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ABSTRACT

This is the fourth in a series of interpretive reports on the use of Computers in Higher Education. This book is based on a 1976-77 survey. The authors developed the questionnaire for the fourth inventory with the cooperation of 18 representatives from instructional research, administrative computer user groups, and other interested parties. The report also contains several interpretive essays designed to identify changes and trends in computer science and computer usage in higher education. Individual chapter titles are: Institutional Resources for Computing; Computer Systems Changes; Computing Center Organization; Administrative Uses of Computers; Instructional Uses of Computers; Changes in Research Computing in Higher Education; Computing in Minority Institutions - 1976-77; Networks and Special Service Organizations; Computer Science-Related Degree Programs at the Associate Level; and Computer Science-Related Degree Programs at the Bachelor's Level. (MP)

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The Fourth Inventory of Computers in Higher Education: An Interpretive Report

edited by John W. Hamblen
and Carolyn P. Landis

EDUCOM Series in Computing and Telecommunications in Higher Education 4

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and Carolyn P. Landis

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EDUCOM Series in Computing and Telecommunications in Higher Education

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Fourth Inventory of Computers in Higher Education: An Interpretive Report
edited by John W. Hamblen and Carolyn P. Landis

Sixteen experts on computing in higher education present their interpretations of the data gathered in the Fourth Inventory of Computers in Higher Education conducted during 1977. They comment on changes in the organization of computing within institutions of higher education, current trends in administrative and instructional uses of computers, and manpower training and utilization. The development of networks and other special service organizations is also discussed, as are changes in research uses of computers and the all-important area of computer financing. Three chapters analyze statistics on computer science and related degree programs at the graduate, four-year undergraduate, and two-year undergraduate levels.

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Overview

Thomas B. Baird and John W. Hamblen

When a technology is changing as rapidly as computing, it is difficult to keep abreast with its extent and application in any segment of society. This is especially true in institutions of higher education in the United States. Over 3,000 institutions or campuses are almost equally distributed between public and private control. Since most colleges and universities have separate governing boards, no single agency tracks computing and the academic discipline of computer science in U.S. higher education.

To provide information about computers and computer usage in institutions of higher education the National Science Foundation (NSF) has funded four studies of computers in higher education during the past fifteen years. The study conducted in the academic year 1964-65 was published by the Southern Regional Education Board. The 1966-67 and 1969-70 studies were published by NSF, and the statistical report for 1976-77 on which this book is based was published by EDUCOM. Each publication represents a myriad of details and statistical summaries about computers in higher education. In the most recent survey report, institutions were stratified into forty groups, and up to ninety different data summaries were prepared for groups and combinations of groups. To the knowledgeable analyst, the four inventories of computing in higher education contain a wealth of information and represent snapshots of the status of computing in higher education during the period 1964-77.

Summaries of the data were made according to the following classifications in the fourth inventory (FICHE): *control:* 1) public, and 2) private; *highest level of offering:* 1) associate degree, 2) bachelor's degree, 3) master's degree, and 4) doctorate; *enrollment (Fall 1975) class:* 1) below 500, 2) 500-2,499, 3) 2,500-9,999, 4) 10,000-19,999, and 5) 20,000 and above. Summaries were also produced by state, but these were not published.

Because of the large volume of data presented in the Fourth Inventory of Computers in Higher Education and its predecessors, the NSF has made possible this publication of interpretive reports. Each chapter in the book represents an analysis of past and present data along with the authors' interpretations of the significant changes in trends and directions. These narrative reports give meaning and usefulness to the data.

The authors of the reports were selected for their expertise; almost all of them have been previously published on the topic they discuss here. Most of them are, or were, professors, chairmen, directors, etc., from the academic community, with one exception. David Nyman now works with a large accounting firm, but he served for many years at the Illinois State Board of Higher Education and was responsible for master planning and budget review of all computing activities in the state colleges and universities. The varied background and affiliations of the authors make this collection of interpretive reports interesting and informative.

The Fourth Inventory Design

In the process of designing the questionnaire for the fourth inventory, eighteen representatives from instructional, research, and administrative computer user groups and other interested parties met at NSF to review the questionnaire and make suggestions concerning each item of data to be collected. Most of the authors of the interpretive articles were there and made suggestions. To the extent possible, with restrictions on the length and complexity of the questionnaires, the needs of all groups represented were included.

Continuous forms were designed, as in previous inventories, in order to permit personalization of the questionnaires. The necessary classification codes, name, address, and zip code of the institution were printed on the forms prior to mailing. One complete set of forms was mailed to the "president" of each college or university listed in the USOE HEGIS directory. Additional sets of the form were sent to institutions that had reported multiple installations during the 1969-70 inventory. Other sets of forms could be requested by returning a postcard that was included in the mailing.

Three follow-up mailings were made to nonrespondents, and the institutions were encouraged to make collect calls to FICHE if questions arose. Nearly 350 phone calls were received. These calls proved to be very useful to both the respondents and the authors; we learned how questions were being interpreted and how much attention was being given to the responses.

FICHE staff took great care to edit, codify, and proofread the data to insure that the information was used as the respondents intended. When questions arose concerning the responses, phone calls were made to obtain clarification. The response to the phone calls indicated that the respondents had made a conscientious effort to answer the questions as accurately and thoroughly as they could.

The Interpretive Essays

To identify changes and trends in computer science and computer usage in higher education, the authors compared FICHE with previous inventories funded by NSF. The questionnaires used for those studies, particularly the last two, were similar to the ones used for this study. Most of the differences reflect the availability of new options due to the ever-changing technology. Some of the differences resulted from simplification of later questionnaires. Other data for comparisons were used where available and are noted by the authors.

To properly appreciate the growth of computer installations and computer science degree programs it is necessary to relate that growth to the growth of higher education in general. Chapter 1 by Dr. Bruce Alcorn begins with this information.

The number of institutions of higher education increased 27% during the ten years from 1966-67 to 1976-77. The number of students in colleges and universities increased by 30% during the same period. However, larger colleges enjoyed such growth often at the expense of smaller institutions. During the ten-year period, a 97% increase in the number of computer installations only raised the proportion of institutions having computers from 40% to 69%. The paradox of the number of computers in "small" colleges and universities actually diminishing during the period 1969 to 1976 is explainable by the fact there were 114 less institutions in the "below 500" category in 1976 as compared to 1969. Dr. Alcorn discusses finances, staff, computers, computer science degree programs, and looks at the trends while considering types of institutions, degrees offered, public versus private control, size, and geographic region. His understanding of the changes and trends is enhanced, without doubt, by his close association with the 1969-70 inventory.

Dr. Vincent Swoyer describes modern computer systems as "multiple generations of technology" as he discusses "Computer System Changes" (Chapter 2) and "Computer Center Organization" (Chapter 3). The vendor with the largest number of computers on campuses, the single most popular computer model, and the order of popularity of computer languages revealed in Chapter 2 may surprise some readers. Dr. Swoyer's experience with the four computing inventories and the five surveys done by Keenan (see bibliography at the end of Chapter 3) at the University of Rochester is supplemented by his experience in a follow-up study for the 1969-70 inventory in which he visited approximately thirty institutions.

Although 45% of the institutions reporting indicated one or more uses of computing for administrative purposes, a high degree of sophisticated use of computers in administration is not evident. The function most often reported was "printing class rosters." This relative lack of sophistication in computer use by administrators is somewhat puzzling in view of the fact that computing expenditures for administrative purposes increased from 34% of the total of computing expenditures in higher education for 1969-70 to 45% in 1976-77. Charles Thomas, executive director of CAUSE, discusses administrative uses in Chapter 4.

Are we to see "computing in every home?" Dr. Karl Zinn, discussing instructional uses of computers in Chapter 5, says "We must go beyond extrapolation of data from the inventories to realize the future in computer influenced instruction. . . . Breakthroughs in price, size, simplicity, and usefulness are such that we are in the beginning of a revolution of change for using computers as educational tools. . . . It appears that new and intellectually exciting times are upon us. . . . As computers become more available and personalized they become more useful to the scholar."

If the revolutionary changes predicted by Dr. Zinn do not take place as quickly as expected, Dr. Peter Lykos can probably tell us why. In Chapter 6 Dr. Lykos states that "The fact that almost half our current academic faculty was trained before the computer appeared on the scene is a major problem." He strongly encourages continuing education in the use of computers as a research tool within the academic community. Dr. Lykos's interpretations and conclusions have added credence since he is not a professor of computer science selling his product, but a research chemist.

The authors of Chapter 7 have all worked very hard at improving computing at minority institutions, and happily the inventories show much improvement in recent years. Analysis of hardware acquisition dates shows that nearly two-thirds of the computers at minority institutions were acquired in 1974 or later. The authors' credit to AIDP (funded by the U.S. Department of Health Education and Welfare programs, by NSF, and by gifts from DEC) is well placed. Assistance from the ECMI (Educational Computing in Minority Institutions) funded by NSF has also been a major influence. Given time and continued direction, the desired maturity of computing resources at these institutions will become a reality.

The author of a report on "Networks and Special Service Organizations" (Chapter 8) might be expected to be very heavily pro-networks. Dr. Charles Mosmann, however, presents a very balanced discussion of the data and their meanings. "The need for networks to supplement the services available from any individual campus computer center continues and grows. . . . Many of the promises of networks have been excessive. . . . Networks will never supply the bulk of computing in colleges and universities or even a large part of it. . . . Ninety percent of computing can be better done on campus. . . . Networks should exist to facilitate the ten percent that cannot." Any institution or governing body considering networks should read Chapter 8 very carefully.

The authors of the three chapters concerning the associate, baccalaureate, and graduate-level degree programs have all been involved in the development of curriculum recommendations of the Association for Computing Machinery (ACM). Without a doubt, the popularity of "computer science" among the computer-related degree programs can be attributed to these ACM recommendations. The shortage of qualified faculty appears to be a major problem at all levels, especially at the two undergraduate levels. If industry continues to demand employees with undergraduate degrees in computer science and to pay high salaries to obtain them, universities will continue to find it difficult to attract enough graduate students to Ph.D. programs in computer science. If too few students enter the graduate programs, too few will graduate with Ph.D.'s to meet the need for computer science faculty.

In Chapter 12, Dr. Orrin Taulbee discusses "Manpower Training" and notes problems of supply and demand. "Due to the high demand for graduates there is a danger of deterioration in quality of programs. Qualified faculty are in short supply." Care must be taken at all levels to assure quality and especially when starting new degree programs.

As federal support for computing has been reduced (on a percentage basis), support from institutions of higher education has been increased significantly. As David Nyman states in Chapter 13, this shift in support clearly indicates that computers have become an integral part of the academic community.

One pleasing fact is pointed out in several chapters. In spite of the long inflationary period covered by this study, "The amount of computing capability that one dollar purchased in 1976 was significantly greater than that purchased in 1969." There are many positive changes in computing in higher education revealed in these reports, but the breakthroughs in size and cost are probably dominant in pushing computers to more and better usage throughout the academic community.

The Fourth Inventory of Computers in Higher Education

1

Institutional Resources for Computing

Bruce K. Alcorn

An Overview of All Institutions in the Inventories

Introduction

This section will analyze all of the institutions of higher education as a group. The data here will frequently serve as the base of comparison for the discussion of later sections of this chapter.

In 1966-67 there were 2,477 colleges and universities in the United States. The total number of institutions of higher education in the United States increased 27% in the decade between the second and fourth inventories of computing in higher education, while total enrollment increased about 30%. The response rate (the proportion of institutions responding to the inventory), on the other hand, decreased from 79% in 1966 to 75% in 1969, and it especially dropped off for the most recent study to 58% responding. The rate of decline from study to study, interestingly enough, is very similar to the rate of decline of federal funds expended for computing in these same institutions. As will be shown later, the percentage of colleges expending federal funds for computing is higher than the percentage that responded to the survey. However, the rate of decline from 1966-76 in both proportions is similar.

Bruce K. Alcorn is chairman of the Division of Education at Grace College in Winona Lake, Indiana.

Finances

Total expenditures for computing in higher education have skyrocketed. Estimated total expenditures increased 348% between 1966-67 and 1976-77, at an average rate of about 35% per year. The cost per student (total expenditures divided by the total enrollment) in 1966-67 was $26, in 1969-70 it was $57, and in 1976-77 it was up to $88, for an increase of 238% per student cost. Figure 1.1 presents the data in detail.

During the time between inventories there has been substantial change in the sources of funds for computing expenditures, as can be vividly seen in Figure 1.2. The institutions now depend upon internal funding sources to a much larger degree than they did ten years ago. The actual dollar amount from federal government sources is up from 1966-67, but the total expenditures are up to a much larger degree, resulting in a lower proportion from the federal government and other outside sources.

Staff

As powerful, efficient, and speedy as computers are, they still require people to run them. In fact, the estimated number of computer installations increased 97% from 1966-67, while the estimated number of personnel to run those installations increased 106%. It is interesting to note that the proportion of management and clerical staff has remained virtually the same (from 14% to 15% and 15% to 15%, respectively), but the proportion of analysts and programmers has increased (from 33% to 37%), while the proportion of operators has decreased (from 38% to 33%).

The ratio of full- to part-time staff has also changed. In 1966-67 it was 10:6 (ten full-time staff members for every six part-time staff members), but by 1969-70 it had changed to 10:5 and by 1976-77 it was 10:4.

The level of education of staff members is one index of staff quality in colleges and universities. Staff of computer installations in higher education (see Figure 1.3) have become slightly better educated; at least, the proportion with degrees is higher. There has been no change at the doctoral level, a slight increase

Figure 1.1
Estimated Total Expenditures and Cost Per Student
(All Institutions)

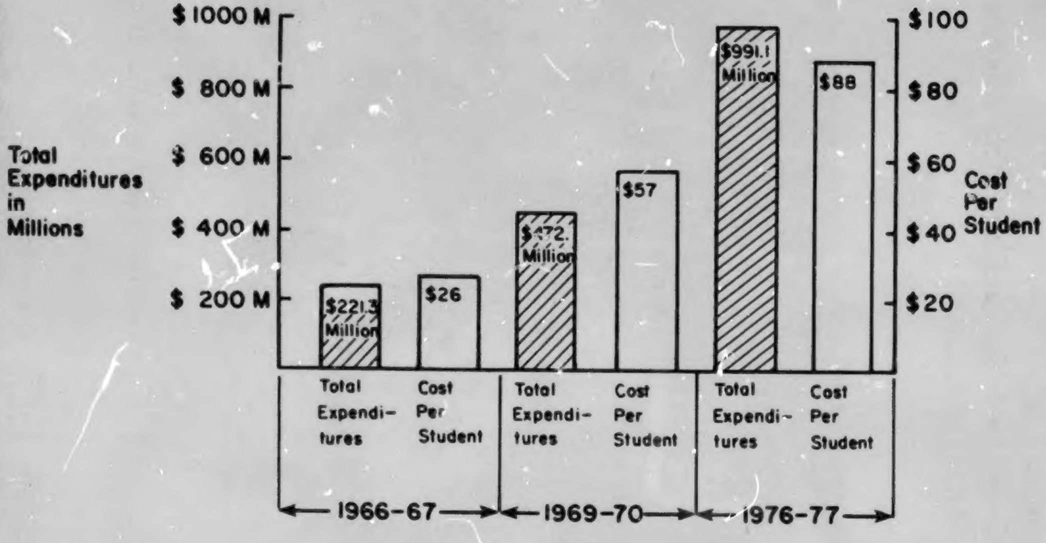


Figure 1.2
Estimated Expenditures by Source of Funds
(All Institutions)

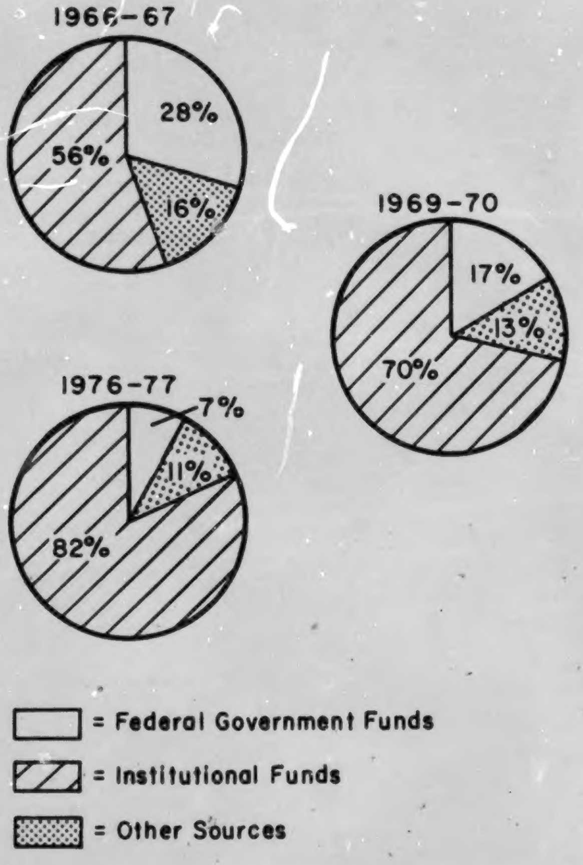
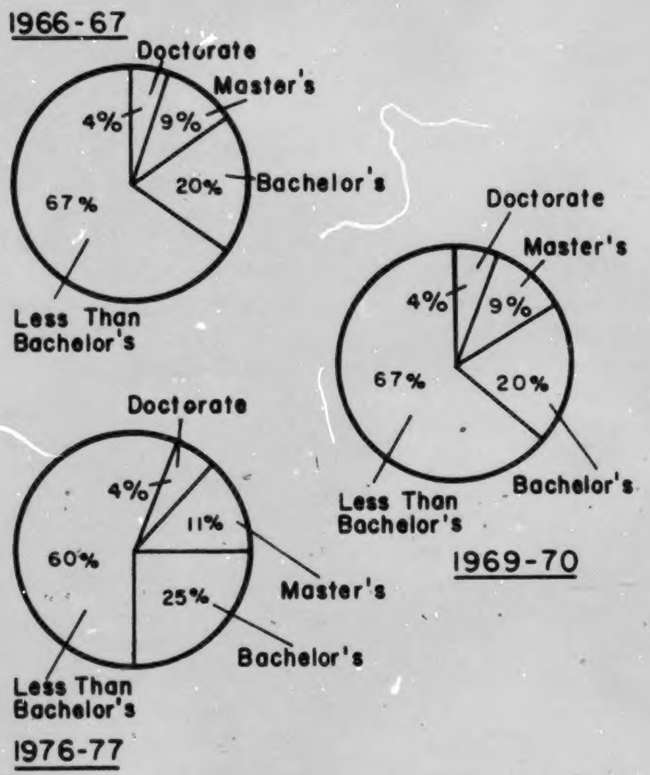


Figure 1.3
Proportion of Computer Installation Staff by Highest Degree (All Institutions)



at the master's level, and a 5% increase at the bachelor's level. Ready access to undergraduates accounts for the high percentage of employees with less than bachelor's degrees.

Computers

As cited earlier, the number of institutions and/or campuses of higher education increased 27% between 1966-67 and 1976-77. During this same time the number of institutions with computer installations increased 115% and the number of installations increased 97%. Another way to look at it is to say that 40% (997) of the colleges and universities had computers in 1966-67, 60% (1,768) in 1969-70, and 68% (2,147) in 1976-77.

Computer Science

The largest number of degree programs in computer science (includes computer science, data processing, computer programming, information systems, and computer science and engineering) have traditionally been found at the associate degree level, and by a wide margin. However, the number of bachelor's degree programs increased so much between 1969-70 and 1976-77 that they are now a close second, (see Figure 1.4). The number of programs has increased at all four levels, but the proportions have shifted due primarily to the size of the increase at the bachelor's level.

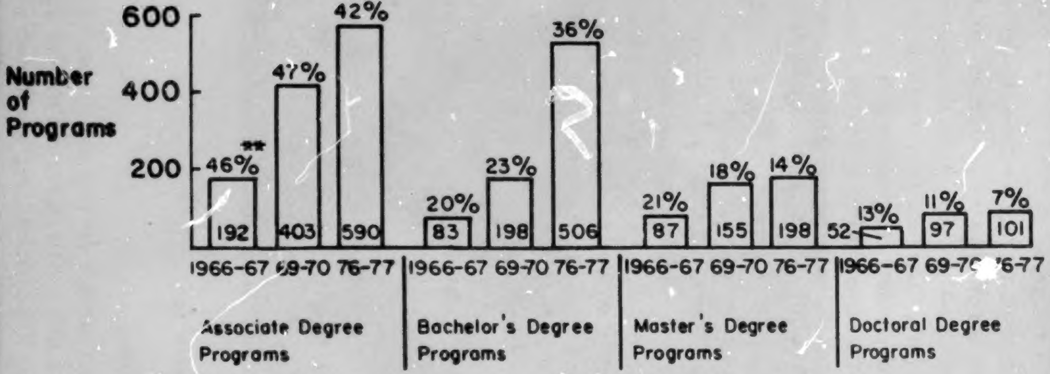
When looking at this from the standpoint of the number of majors (undergraduate vs. graduate) there has been a steady shift toward proportionately more undergraduates (associate and bachelor's degrees) than graduates (master's and doctoral degrees). In 1966-67 the ratio was 4.5:1 (4.5 undergraduates to every graduate), in 1969-70 it was 7:1 and by 1976-77 it had reached 8:1.

Changes in the number of degrees awarded follow general changes in the number of degree programs reported above. The number of degrees awarded increased for each reporting period, but at the doctoral level there was a slight decrease in 1976 compared to 1969.

Trends

The following trends are evident from the data of the inventories of computers in higher education at all institutions.

Figure 1.4
Degree Programs in Computer Science *
(All Institutions)



* This includes curricular programs in computer science, data processing, computer programming, information systems, plus computer science and engineering.

** Percents indicate the proportion of all degree programs for that year which were at that level.

1. The number of institutions of higher education continues to increase.
2. The response rate to these studies has decreased sharply.
3. The proportion of computer installation expenditures supported by the federal government has decreased sharply. (The rate of decrease is quite similar to the rate of decrease in the response rate.)
4. Total expenditures increased 348% while the number of installations increased 97%.
5. The makeup of the staff of the computer installations is changing toward a higher percentage of analysts and programmers, and a lower percentage of operators, toward more full-time and less part-time employees, and toward a slightly better educated staff.
6. The number of institutions having computer installations increased and so did the number of installations at those institutions. Both increases were significantly greater than the increase in the number of colleges and universities.
7. Associate degree programs in computer science still are most abundant, although bachelor's degree programs are now a close second.
8. The ratio of undergraduate to graduate majors in computer science is still increasing slightly.
9. The number of degrees awarded in computer science continues to increase, but at the doctoral level the trend is down.

Major Universities

Introduction

This section will cover the major universities, which, for the purposes of this report, were defined as those institutions with both doctoral programs and enrollments equal to or greater than 10,000 students.

Major universities increased in number to a greater degree (61%) than did all institutions of higher education (27%) between 1966-67 and 1976-77. Most of this increase was due to rising enrollments rather than to more institutions offering doctoral programs. The response rates were significantly higher for the major universities than for all institutions for each of the inventories, but the overall response rate dropped from 1966 to 1976. Between 1966 and 1976, the response rate for major universities dropped from 92% to 72% while it dropped for all institutions from 79% to 58%. Most of the drop occurred in the most recent survey; in 1970 the response rate was 92% for major universities and 75% for all institutions.

Finances

Total computing expenditures for the major universities increased 355% over the ten years from 1966 to 1976, a rate of growth only slightly higher than the increase in total expenditures for all institutions (348%).

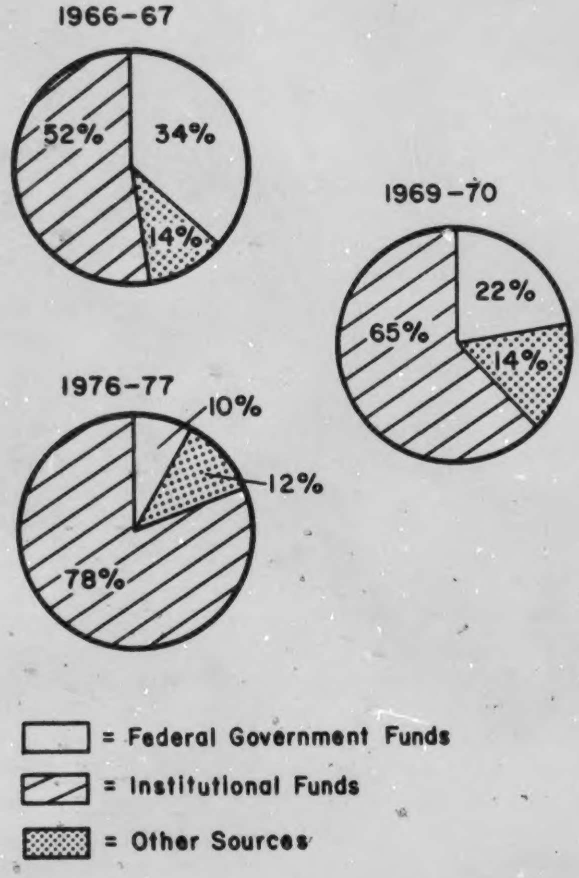
In 1976 major universities have assumed most of the cost of computing, with only 22% of the funds coming from outside sources (see Figure 1.5). In 1966-67 almost half of the funds for computing in these universities came from outside sources. The biggest reason for the change has been the drying up of federal money. This source of funds is supplying a smaller proportion of expenses for computing at major universities. However, federal funds for computing for these institutions increased 30% since 1966-67, while they rose by only 13% for higher education computing in general.

Staff

While the number of computer installations in major universities increased only 16%, the number of full-time equivalent (FTE) staff increased 100% during the decade prior to 1976-77. In 1966-67 there were nineteen FTE staff per installation and by ten years later it had risen to thirty-four. While the number of staff has increased, the proportions by job categories (management, etc.) are approximately equal in 1977 to those in 1967. A slight shift in 1970 toward higher proportions of clerical and operational staff was reversed by 1977 to bring the proportions for 1977 nearly equal to those for 1967. Total changes include: management (from 13% to 13%), clerical (17% to 15%), operations (30% to 32%), and analysts (43% to 40%).

The ratio of full- to part-time employees continues to increase. The most recent figures indicate that there are twenty-

Figure 1.5
Expenditures by Source of Funds
(Major Universities)



six full-time staff members to every ten part-time employees.

The level of education of computing staff members is increasing slightly, particularly at the bachelor's (from 22% to 27%) and master's (8% to 12%) levels. The proportion with less than the bachelor's degree has dropped the most—a decrease of 9% from 1967 to 1977. Refer to Figure 1.6 for the details.

Computers

The 1966-67 and 1969-70 inventories found that every major university had at least one computer installation. The latest study found only a 91% coverage, which may be due to a lack of reporting or to the fact that several campuses have the same code as the parent institution. It is difficult to conceive of a doctoral degree university with more than 10,000 students without at least one computer. The total number of installations increased only 49% since 1967, while the number of universities in this category increased 61%.

Computer Science

Figure 1.7 shows that large universities continue to offer few programs in computer science (and related areas) below the bachelor's degree level. This pattern is no doubt true of other disciplines as well. It is interesting to note that in the earlier years (1966-67) graduate programs were predominant (about 70% of the programs); however, by the time of the latest study the bachelor's degree programs exceeded master's degree programs by 7% (from 41% to 34%), and doctoral programs by 19% (41% to 22%). In terms of the number of degrees awarded, the pattern is even more pronounced, with bachelor's degrees awarded in 1976-77 in computer science comprising 63% of all degrees awarded in this discipline. The remaining proportions of the 5,470 degrees awarded in that year were: associate, 3%; master's, 29%; and doctorate, 5%.

Another way to view this change is to note the ratio of undergraduate to graduate majors for these reporting periods. In 1966-67 there were more graduate students in these fields than undergraduates, since for every eight undergraduates there were ten graduate students. By 1969-70 there were almost two under-

Figure 1.6
Proportion of Computer Installation Staff by Highest Degree
(Major Universities)

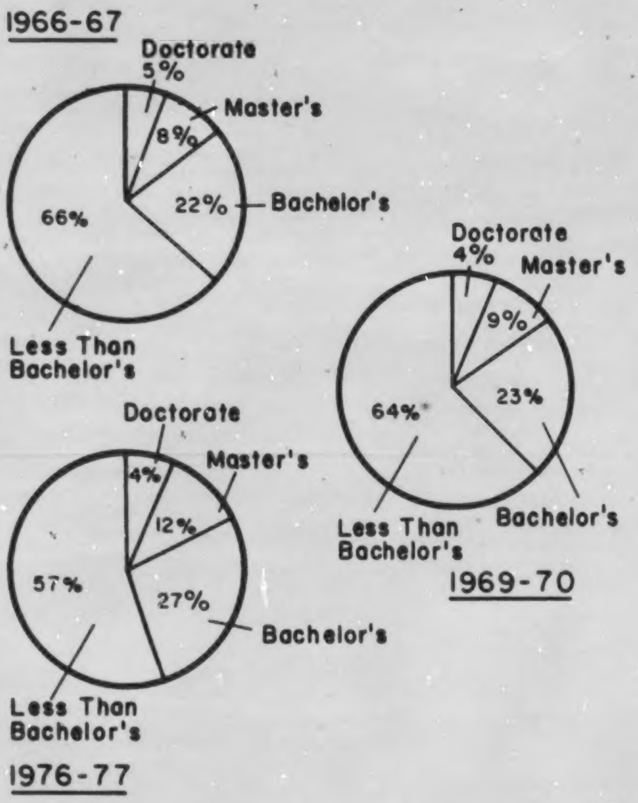
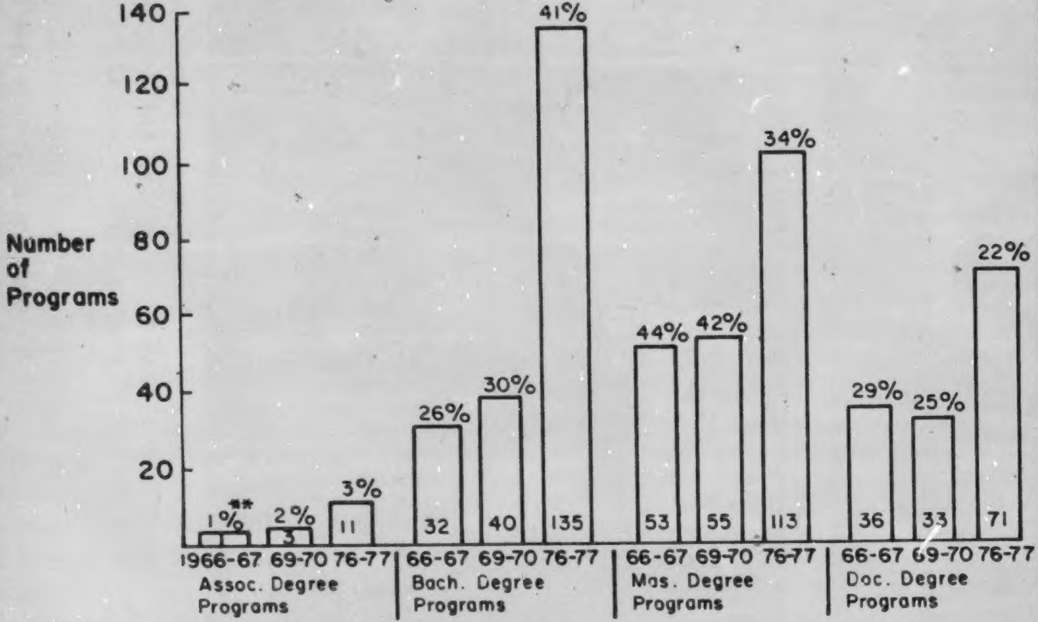


Figure 1.7
Degree Programs in Computer Science *
(Major Universities)



* This includes curricular programs in computer science, data processing, computer programming, information systems, plus computer science and engineering.

** Percents indicate the proportion of all degree programs for that year which were at that level.

graduates for each graduate and by 1976-77 the ratio had increased to three to one.

Trends

The following list contains the more evident trends among the major universities (doctoral degree institutions with at least 10,000 students).

1. The number of major universities increased primarily because more institutions became larger. A few large universities also began to offer doctoral degree programs.
2. The response rates in all of the inventories of computing are higher for the major universities than for the higher education population in general. However, the major universities exhibited a 20% drop in response rate from the 1969-70 inventory to the 1976-77 one, following the pattern set by the rest of the higher education population.
3. The proportion of computer installation expenditures supported by federal funds has decreased sharply. Institutional support for computing constitutes 78% of all expenditures for computing.
4. Total expenditures increased 355% compared with 348% for all institutions from 1966-67 to 1976-77.
5. Computer installation staffs have significantly increased in size.
6. The makeup of the computer installation staff remained almost unchanged. However, there is a general trend toward a slightly better educated staff.
7. Both the number of institutions with installations and the number of installations increased, but at a rate lower than the rate of increase in the number of major universities.
8. The major universities continue to offer little in the way of computer science programs at the associate degree level.
9. The earlier predominance of graduate programs in computer science has been replaced by a sharp increase in both the number of programs and in degrees awarded at the bachelor's degree level.

10. The ratio of undergraduate to graduate majors in computer science continues to increase.

Other Four-Year Institutions

Introduction

The analyses in this section involve all institutions not included in the previous section nor in the following section (two-year institutions). This group then includes all institutions with the bachelor's or the master's degree as their highest offering, plus those doctoral institutions with less than 10,000 students.

Because patterns of expenditures and programs differ within this group of other four-year institutions, they are considered as two groups, which, for convenience, are called colleges with more than 2,500 students and colleges with less than 2,500 students.

The colleges with enrollment above 2,500 increased in number (by 38%) slightly more than the overall rate of increase over the ten years 1967 to 1977. In 1976-77 there were 486 colleges in this category. The response rates (from 83% to 63%) were higher than those for all institutions (79% to 58%) in 1976 compared to 1966, but not as high as for the major universities. The same general decline of 20% in response rate between 1969-70 and 1976-77 was seen in four-year colleges with enrollment over 2,500 as in the whole population. The number of colleges with enrollment below 2,500 students increased 4% from 1970 to 1977. In 1977 there were 746 colleges in this category. Between 1967 and 1970, the number remained at 1,252. In each of the three recent reporting years, response rates for these colleges were slightly lower than the rates for the colleges with enrollment over 2,500 students.

Finances

Total expenditures increased 318% from 1967 to 1977 for colleges with enrollment above 2,500. In 1977 total expenditures for this group were $278.3 million. The pattern of a greater proportion of the expenditures being assumed by the institutions themselves continues as in other categories of institutions.

The $1.8 million (12%) decline in the amount paid for with federal funds is no doubt the major reason for this. In 1977 only $14.6 million came from federal sources for this category of college. Institutional support for computing is now up to 86% for colleges with enrollment over 2,500. The details of this can be seen in Figure 1.8A.

Total expenditures for computing by colleges with less than 2,500 students increased only 64% between 1966-67 and 1969-70 but 151% between 1969-70 and 1976-77. In 1976 small colleges spent $110.7 million for computing. The increase from 1966-67 to 1976-77 was 271%. This increase, though sizable, was not as high as that for the larger colleges. Federal funds for small colleges decreased 14% between 1966-67 and 1969-70, but increased slightly by 1976-77 (from $8.1 million to $8.5 million). Institutional support for computing by small colleges with enrollment under 2,500 is now up to 83% as can be seen in Figure 1.8B.

Staff

While the number of large colleges with installations increased 41% and the number of institutions increased 51% from 1967 to 1977, the number of FTE staff increased 83%. The size of the staff of each computer installation seems to be increasing. In 1966-67 there were a little more than 10 FTE staff members per installation, in 1969-70 it was up to about 12.5, and in the latest study it had risen to just over 13.

The proportion of staff in each of the four job categories in large colleges stayed much the same over the ten-year period from 1967 to 1977 except for a slight shift toward more analysts and programmers (from 31% to 35%) and fewer operators (37% to 34%). Even smaller shifts occurred in clerical (18% to 15%) and management categories (15% to 16%). The ratio of full- to part-time employees continued to increase to the point where it became almost 2:1.

As in the other institutions, in 1976-77 the computing staff members in large colleges are slightly better educated than they were in 1966-67 (see Figure 1.9A).

The computer installation staff sizes (FTE staff per installation) at small colleges were considerably smaller than at the

Figure 1.8 A
Expenditures by Source of Funds (Other Four-Year Institutions— Above 2500 Students)

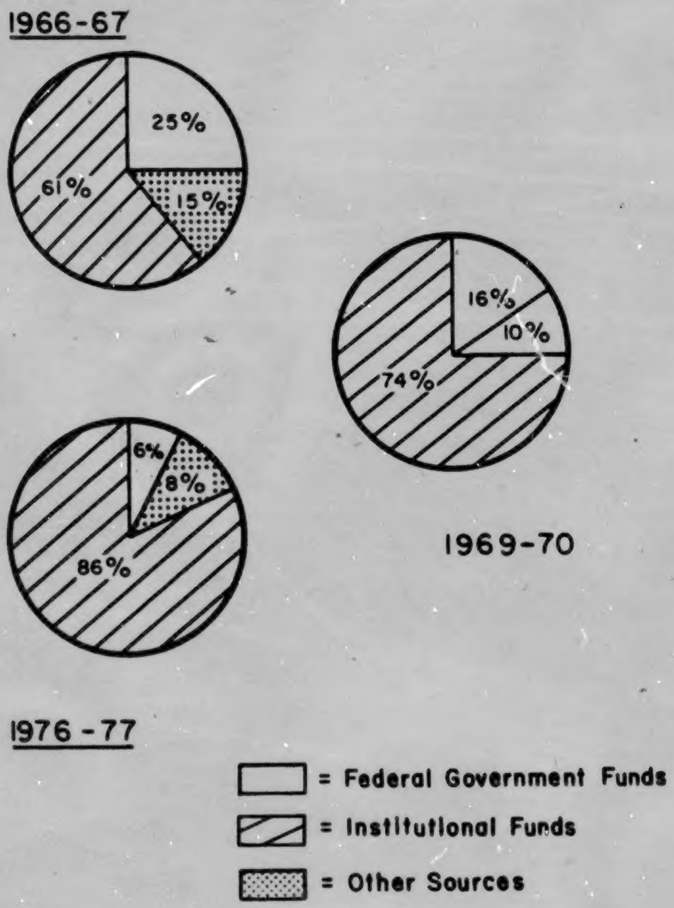


Figure 1.8 B
Expenditures by Source of Funds (Other Four-Year Institutions—Below 2500 Students)

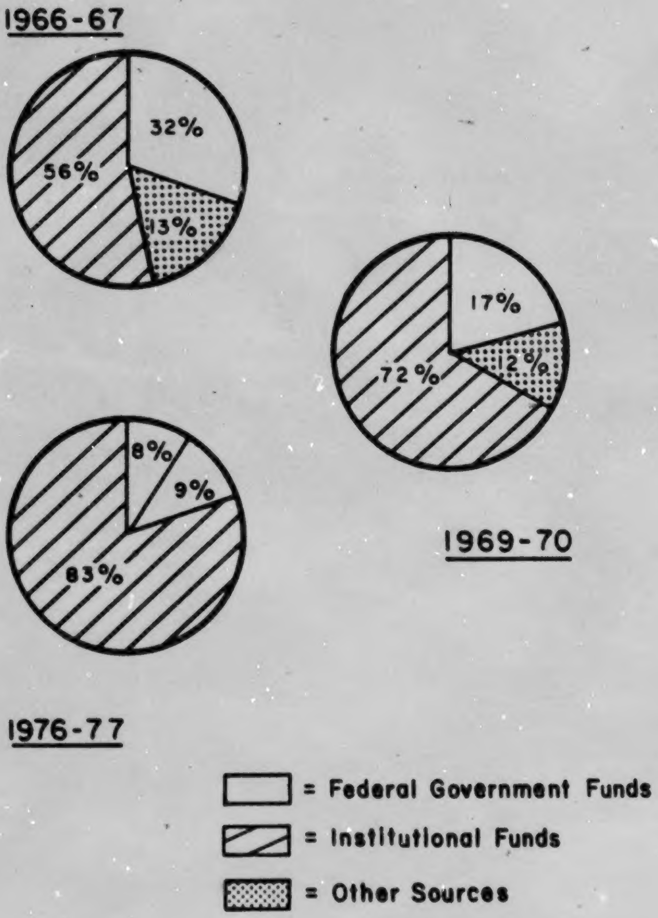
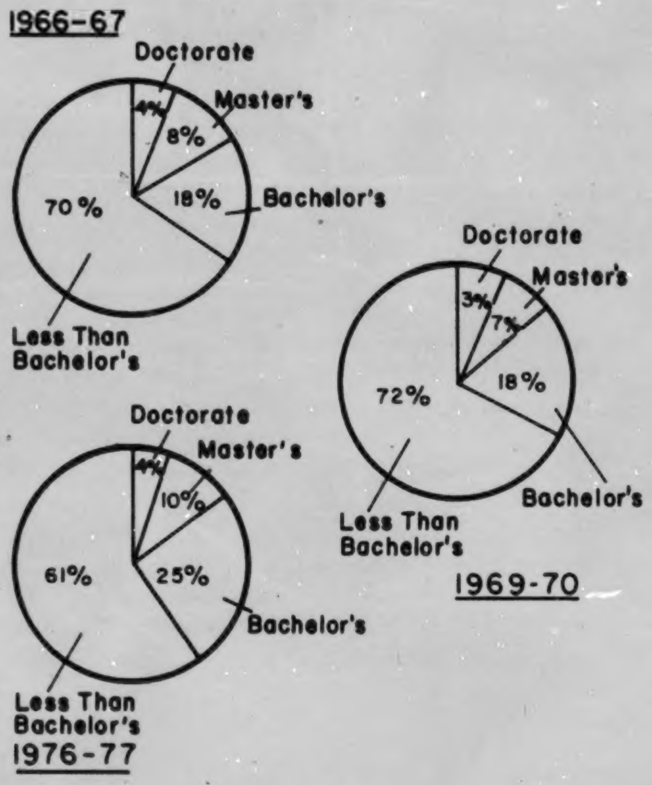


Figure 1.9 A
Proportion of Computer Installation Staff by Highest Degree (Other Four-Year Institutions— Above 2500 Students)



larger institutions. In addition, staffs are staying the same size or are even getting slightly smaller. The number of FTE staff per small college computing installation for the last three studies is 4.88, 3.71, and 4.56. This is one-third of the size found at the larger colleges.

The percentage of staff in each of the four job categories stayed basically the same from 1967 to 1977: clerical, 15% to 14%; management, 16% to 19%; analysts and programmers, 32% to 32%; and operators, 37% to 36%. In comparison to the larger colleges, these seem to have a slightly higher proportion of management staff and slightly lower proportion of clerical staff. The ratio of full- to part-time employees continues to increase as with other institutions. It is now a little less than 2:1.

There has been a significant increase in the proportion of small college staff members with bachelor's degrees (up to 30%) and a similar decrease in the percentage of staff members with less than a bachelor's degree. Above the bachelor's level, the proportions have stayed approximately the same (see Figure 1.9B).

Computers

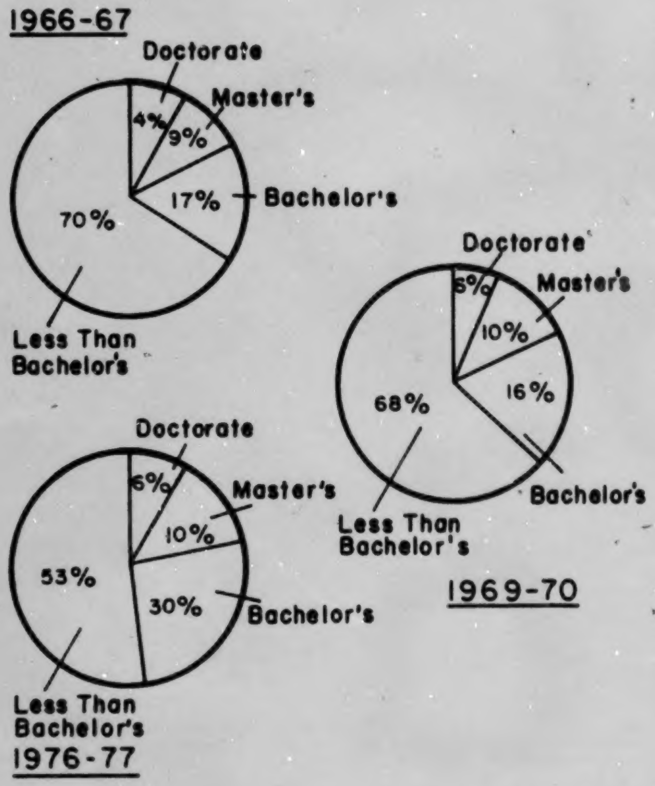
The proportion of large colleges with at least one computer installation increased from 87% to 95% between 1967 and 1977. As mentioned earlier, the number of institutions in this category increased 38%, but the number of institutions with installations increased 51% and the number of installations increased 41%. In 1977, 464 of a total of 486 large colleges maintained 580 computing installations.

The proportion of small colleges with at least one computer installation more than doubled between 1967 and 1977, but at 57% it is still considerably less than for other institutions. The number of small colleges increased from 1,252 to 1,293 over the ten-year period. The number of small colleges with computers rose from 321 in 1967 to 663 in 1970 and to 748 by 1977.

Computer Science

In terms of degree programs in computer science and related areas the bachelor's degree programs have remained most predominant in the large colleges (see Figure 1.10A). In terms

Figure 1.9 B
Proportion of Computer Installation Staff by Highest Degree (Other Four-Year Institutions—Below 2500 Students)



of numbers of degrees awarded, in 1977 this trend is even more evident. More than three-fourths (76%) of all (4,993) degrees in this discipline are at the bachelor's level. The other degree categories in 1977 are: associate, 6%; master's, 18%; and doctorate, 1%. Although the number of degrees in each category increased since 1966 (443), the proportions decreased for all categories except bachelor's. Proportions in 1966 were: associate, 29%; bachelor's, 38%; master's, 15%; and doctorate, 18%. The ratio of undergraduate to graduate majors increased from about 3.5:1 to about 5.8:1.

In the small colleges bachelor's degree programs in computer science and related areas were about as predominant as in the larger ones, at least in terms of proportion. However, the number of programs is much smaller in the small colleges and the growth patterns are different. At the doctoral and master's degree levels, degree programs are almost nonexistent (see Figure 1.10B). This pattern of the number of degrees awarded at each level is similar for small colleges and large colleges over the ten-year period with one exception. Associate degrees increased in number much more for smaller colleges. The breakdown for the fifty-eight degrees granted in smaller colleges in 1967 was: associate, 9%; bachelor's, 7%; master's, 78%; and doctorate, 7%. For the 685 degrees awarded in 1977, the pattern was: associate, 22%; bachelor's, 69%; master's, 2%; and doctorate, 0%.

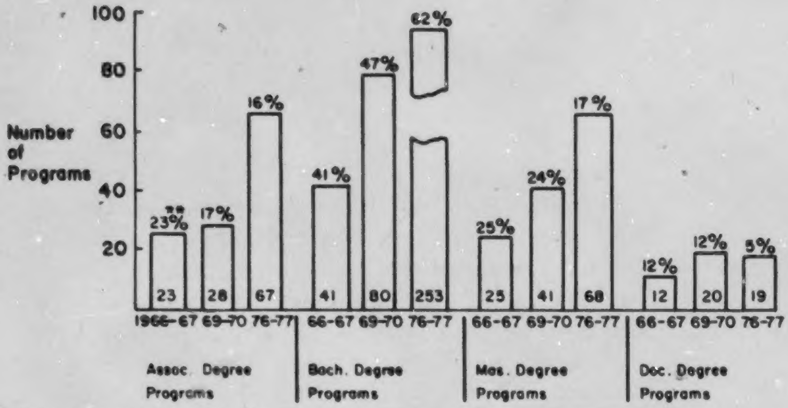
The ratio of undergraduate to graduate majors in small colleges continues to increase. In 1966-67 there were more graduate than undergraduate students; however, in 1976-77 there were about twenty undergraduates for each graduate major.

Trends

Several trends, listed below, are evident among the large colleges with more than 2,500 students, and the doctoral degree institutions with more than 2,500 but less than 10,000 students.

1. These institutions increased in number at a rate slightly greater than the increase for all institutions.
2. The response rates were higher than the overall rate, but less than that for the major universities. The same general decline for the latest inventory exists.

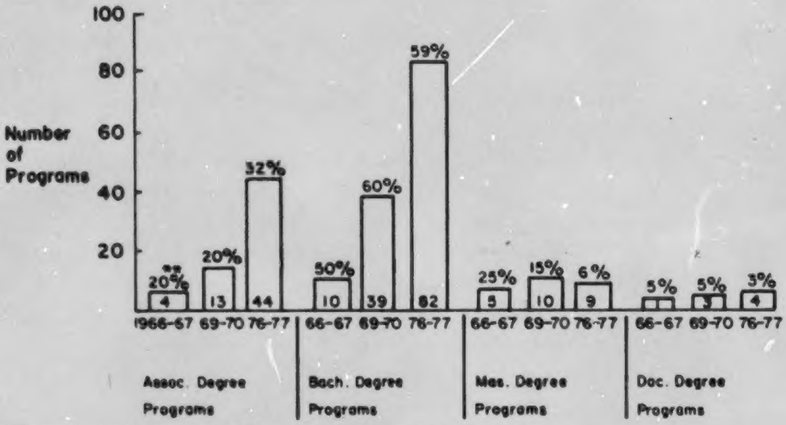
Figure 1.10 A
Degree Programs in Computer Science *
(Other Four-Year Institutions— Above 2500 Students)



* This includes curricular programs in computer science, data processing, computer programming, information systems, plus computer science and engineering.

** Percents indicate the proportion of all degree programs for that year which were at that level.

Figure 1.10 B
Degree Programs in Computer Science *
(Other Four-Year Institutions— Below 2500 Students)



* This includes curricular programs in computer science, data processing, computer programming, information systems, plus computer science and engineering.

** Percents indicate the proportion of all degree programs for that year which were at that level.

3. Both proportion and actual dollars of computer installation expenditures supported by federal funds has decreased sharply. Institutional support is up to 86%.
4. Total expenditures increased 318% compared with 348% for all institutions.
5. Computer installation staffs have increased in size.
6. The makeup of the computer installation staff changed slightly toward a smaller proportion of operators and a greater proportion of analysts and programmers, toward more full-time and fewer part-time employees, and toward a slightly better educated staff.
7. The percentage of these institutions with at least one computer installation has increased to about 95%.
8. Bachelor's degree programs in computer science continue to be most dominant, but associate degree programs are now second, having gone ahead of the master's degree programs.
9. The ratio of undergraduate to graduate majors in computer science continues to increase.

Similar trends are evident in small colleges (institutions with less than 2,500 students), not including the colleges that grant only associate degrees.

1. The number of these institutions increased by 4% from 1969-70 to 1976-77.
2. The response rates declined as they did in other institutions.
3. Federal funds for computer expenditures increased between 1969-70 and 1976-77, but the proportion continues to decline. Institutional support is up to 83%.
4. Total expenditures increased 271% compared with 348% for all institutions.
5. The size of computer installation staffs has stayed the same or even declined.
6. The makeup of computer installation staff stayed basically the same, but they have a slightly higher proportion of management staff and a slightly lower proportion of clerical staff. There is also a trend toward more

full-time and fewer part-time employees, and a definite increase in the proportion of staff with bachelor's degrees and a similar decrease of staff at the less than bachelor's degree level.

7. Only 57% of these institutions have a computer installation.
8. The same pattern of the proportion of computer science degree programs at the various levels exists here as in the larger institutions.
9. The ratio of undergraduate to graduate majors continues to increase.

Two-Year Institutions

Introduction

The junior and community colleges discussed in this section are identified here as those whose highest degree offering is the associate degree.

The number of two-year colleges grew rapidly between the computer inventories taken in 1967 and 1970. By 1970 there were 1,049 colleges in the community and junior college group. There was a 55% increase in the number of these institutions between 1967 (773) and 1977 (1,196). Similar to the pattern exhibited by all other institutions, the community and junior colleges' response rate also declined (from 76% to 67%) between 1967 and 1970. For the latest inventory, the response rate was 55%, or 3% less than the overall response rate. This response rate pattern is the same as the pattern for federal funds for computing for these institutions. Recall that in other groups the response rate pattern also followed the pattern of federal aid to computing.

Finances

Total expenditures for computing increased 622% between 1966-67 ($21.6 million) and 1976-77 ($155.9 million) yielding the highest growth rate of all groups, and the institutions consistently provided the highest proportion of funds for computing; internal funds now constitute 88% of expenditures for computing in community and junior colleges. Some of this is no doubt due to the low amount of federal funds for computing for the two-year colleges. Federal funds did increase from $1.5 million in 1967 to $2 million in 1977, but that is far below the level of federal funding for computing in the other types of colleges. Figure 1.11 illustrates the trend toward greater reliance on internal funds for computing in two-year colleges.

Staff

The number of FTE staff in community and junior colleges increased 294% during the decade prior to 1976-77 while the number of institutions with computer installations increased 160% and the number of installations themselves increased only 131%.

The size of each installation staff is increasing (the number of FTE staff per installation rose from 3.9 in 1966-67 to 4.1 in 1969-70 to 5.6 in 1976-77) but it is still considerably smaller than in the four-year institutions.

The ratio of full- to part-time staff is increasing more rapidly at the two-year colleges than at the four-year colleges. At the two-year colleges it changed from 1.52:1 in 1966-67 to 2.12:1 in 1969-70 to 3.16:1 in 1976-77.

The proportion of the staff in each of the job categories changed between 1966-67 and 1969-70, but since then it has stayed essentially the same. Percentages for each category for the years 1966-67, 1969-70, and 1976-77, respectively, were: clerical, constant at 15%; management, from 25% to 18% to 18%; analysts and programmers, 24% to 32% to 34%; and operators, 35% to 36% to 33%. The earlier change was a decline in the management proportion and an increase in the analyst-programmer proportion. For each inventory, the management proportion of computing staff at two-year colleges is higher than for all other colleges.

The educational level of the computing staff has stayed about the same. There are fewer doctorates on these staffs than at the other colleges, a pattern that is typical of all staff at two-year colleges. See Figure 1.12 for details of this pattern.

Figure 1.11
Expenditures by Source of Funds
(Two-Year Institutions)

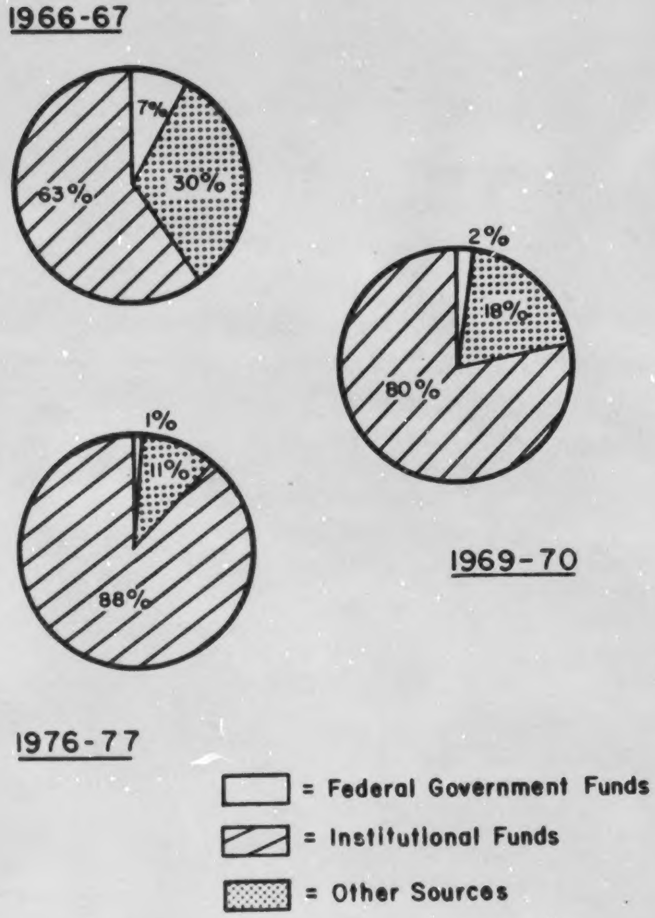
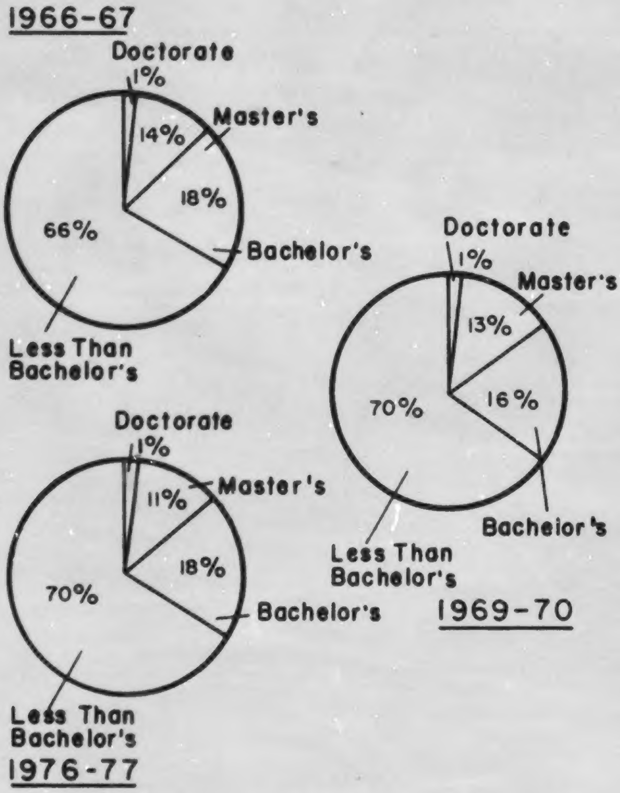


Figure 1.12
Proportion of Computer Installation Staff by Highest Degree
(Two-Year Institutions)



Computers

The proportion of two-year institutions with computing installations increased from 39% to 65% between 1967 and 1977. While the number of these institutions increased 55% (from 773 to 1,196), the number of installations increased 131% (from 341 to 789), and the number of institutions with installations increased 160% (from 298 to 776).

Computer Science, Data Processing, and Related Degree Programs

In community and junior colleges, degree programs are offered at the associate degree level. Computer science, data processing, and related degree programs are increasing in numbers, and so are the number of degrees awarded in these disciplines. The largest increase occurred between 1966-67 and 1969-70, when the number of programs increased from 162 to 388 and degrees awarded grew from 1,179 to 6,141. In 1976, a total of 458 programs awarded 7,754 associate degrees.

Trends

The trends at the two-year or associate degree institutions are as follows:

1. The response rate was consistently 3% under the overall response rates.
2. The proportion of expenditures paid with federal funds continues to decline; however, the actual dollar amount increased for 1976-77. The amounts have been considerably less for two-year or associate degree inventories. Institutional support therefore has been high and it now stands at 88%.
3. Total expenditures increased 622%, compared with 348% for all institutions.
4. Computer installation staffs are smaller than at the other types of colleges, but they also have increased.
5. The makeup of the computer installation staff changed between 1966-67 and 1969-70 but it has been basically unchanged since. The management proportion is larger

than for other institutions. The trend toward more full-time and less part-time employees continues, however the educational level of the staff remains much the same.

6. The percentage of two-year colleges with at least one computer installation increased to 55%.
7. The number of computer science programs and degrees awarded has increased, but the largest increase occurred between 1966-67 and 1969-70.

Comparisons

Introduction

The analyses in this section are more current in that no real effort has been made to look at the results for the earlier inventories. The emphasis instead is on selected comparisons within the 1976-77 data beginning with a comparison of the private and the public institutions, then the very small versus the very large institutions, and finally a brief geographic evaluation.

Private versus Public Institutions

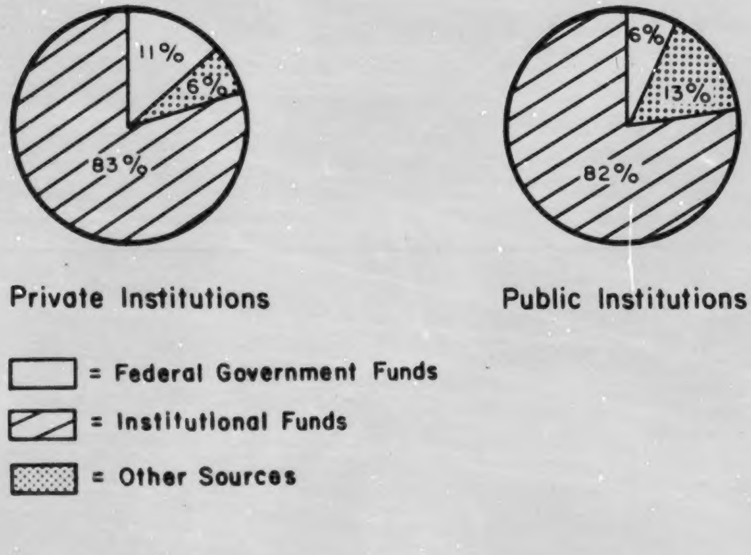
There were 118 (8%) more private than public colleges and universities in 1976-77, yet the total enrollment of the public institutions exceeded that of the private ones by 6.4 million students or 266%. The average enrollment of each private institution was 1,492, and the average for each public institution was 5,825 students.

Finances

The public institutions spent more than 2.5 times as much as the private colleges for the operation of their computer installations. In terms of federal funds, they spent nearly 1.5 times as much as did the private institutions. On a per institution basis annual expenditures for computing in the private institutions averaged $167,000, but in the public colleges the average was $477,000. On a per student basis, the expenditures in the private institutions averaged $112, but in the public colleges the average was $82. Federal funds for computing in the colleges constituted a greater proportion of general funds for private colleges. In 1977, the federal government contributed $28.3 million to computing at private colleges (11% of total expenditures) and $40.2 million to computing at public colleges (6% of total expenditures).

Both groups supported their computer operations with institutional funds in about the same proportions. Federal funds averaged $17,000 per institution or $12 per student in the private sector, and $27,000 per institution or $5 per student in the public sector. Figure 1.13 illustrates the proportion of federal, internal, and other funds expended by public and private colleges in 1977.

Figure 1.13
Expenditures by Source of Funds (Private vs. Public)



Private Institutions

Public Institutions

Staff

The public colleges and universities had larger computer installation staffs (13 FTE staff per installation) than did the private schools (7 FTE staff per installation) which is logical since public institutions serve more students. The proportions of the staff in the various job categories and their educational levels were about the same for both public and private colleges. The lower proportion of managers in public institutions is consistent with larger average staff size. In terms of the ratio of full- to part-time staff, the private institutions used more part-time staff—a pattern again consistent with larger staffs for public institutions. Proportions of job categories and degree levels are illustrated in Figures 1.14A and 1.14B.

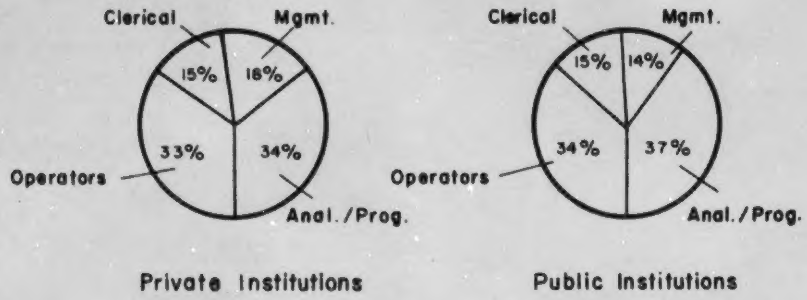
Computers

More of the public institutions (1,281 or 85%) had a computing installation than did the private colleges (865, or 53%). In comparing the number of installations (1,762 public and 1,044 private), the number of institutions with computers, and enrollment, there were about 1,232 students per installation in private schools, and 4,240 students per installation in public schools.

Computer Science

It is quite evident that most of the associate degree programs were in the public colleges, but this is not surprising since almost 81% of the associate degree institutions were public in control. Within the public colleges, associate degree programs comprised 45% of all computer science degree programs, bachelor's degree programs comprised 32%, and master's degree programs made up 15%. Within the private colleges, associate degree programs comprised 20% of all computer science degree programs, bachelor's degree programs comprised 52%, and master's degree programs made up 18% (see Figure 1.15). The private colleges award a small number of degrees in computer science in relation to public colleges, as can be seen in the following data from 1977:

Figure I.14 A
Proportion of Computer Installation Staff by Job Categories and Highest Degree (Private vs. Public Institutions)



	Public	*Private*
associate degree	7,871	359
bachelor's degree	7,678	1,816
master's degree	2,176	980
doctorate	256	88

Computer science majors on public campuses constituted a larger proportion of the student body (1 computer science major per 85 students) than they did on private campuses (1 computer science major per 155 students).

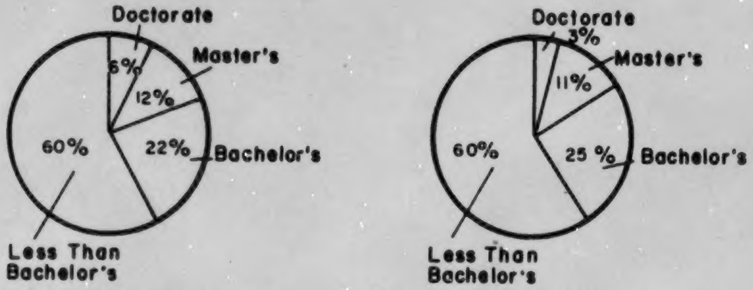
Summary

1. The public institutions are not as numerous, but they are significantly larger than the private institutions.

2. The private colleges spent $112 per student for computer expenditures and received $12 per student in federal funds for those expenditures. The public colleges spent $82 per student and received $5 per student in federal funds.

3. The public institutions used 13 FTE staff per comput-

Figure 1.14 B
Proportion of Computer Installation Staff by Job Categories and Highest Degree (Private vs. Public Institutions)



Private Institutions

Public Institutions

ing installation, and employed almost 3 full-time individuals for each part-time employee. The private institutions used 7 FTE staff per installation, and employed about 1.5 full-time individuals for each part-time employee.

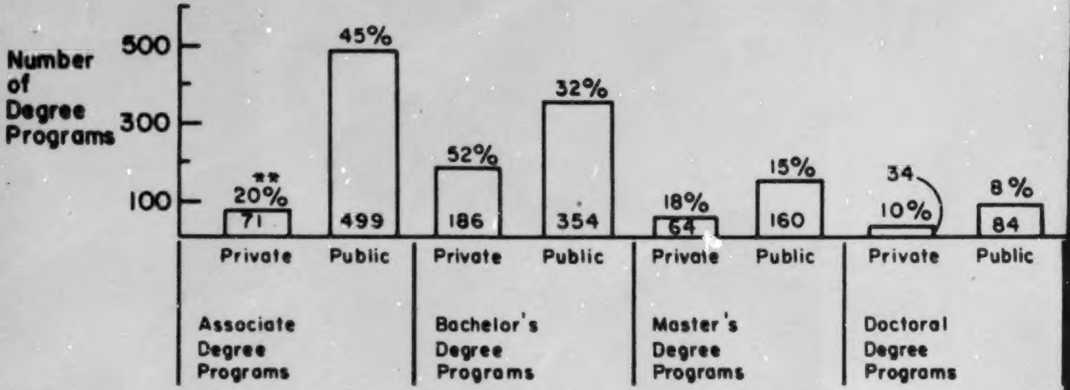
4. The private colleges had a smaller percentage of campuses with computers (53%) than the public colleges (85%).

5. The public campuses had the majority of the associate degree programs in computer science and those programs constituted close to half of all computer science degree programs. On the private campuses more than half of such programs were at the bachelor's degree level.

Very Small versus Very Large Institutions

The 662 very small institutions (those with enrollments less than 500) are six times more numerous than the 112 very large ones (those with enrollments over 20,000). However, they enroll only one-twelfth the number of students (0.2 million compared to 2.7 million). The small colleges each had an average of 333 students, while the large ones averaged 23,995

Figure 1.15
Degree Programs in Computer Science *
(Private vs. Public Institutions)



* This includes curricular programs in computer science, data processing, computer programming, information systems, plus computer science and engineering.

**Percents indicate the proportion of all degree programs for that year which were at that level.

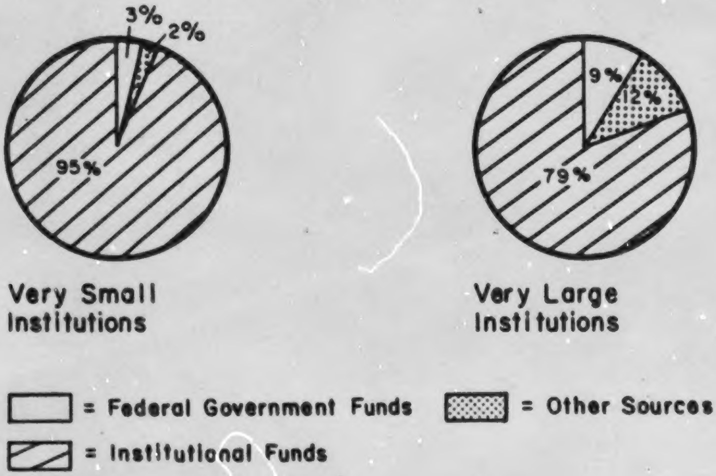
each. Very small colleges responded less enthusiastically to the fourth inventory of computing in higher education (59%) than did the very large institutions (60%).

Finances

Comparing total expenditures for these two classes of colleges is almost like comparing apples and oranges. The very large institutions expended a total of $350.1 million for computing, or $3,125,892 per institution and $130 per student. The very small ones spent $6.5 million for computing, or $9,819 per institution and $29 per student.

The very small institutions supported their installations with their own funds to a much higher degree than did the very large ones (see Figure 1.16). This is probably due to the fact that there

Figure 1.16
Expenditures by Source of Funds
(Very Small vs. Very Large Institutions)



is less money available for small institutions from sources outside. In all categories—total funds, funds per institution, and funds per student—the very large institutions received more money from outside sources by a large margin. For example, the small institution received $.91 per student from federal sources and $.45 per student from other sources, while their large counterparts received $11 and $16, respectively.

Staff

The staff of the two classes of institutions are rather similar in terms of their educational level. The small colleges tended to have a slightly larger proportion of management and a very much smaller proportion of operators. Both of these facts are no doubt due to the small size of the staff and the smaller computers at small colleges. The small installations need a manager, but installations can get fairly large before a second manager is needed. However, large installations need more operators, so that proportion goes up. Refer to Figures 1.17A and 1.17B for the details.

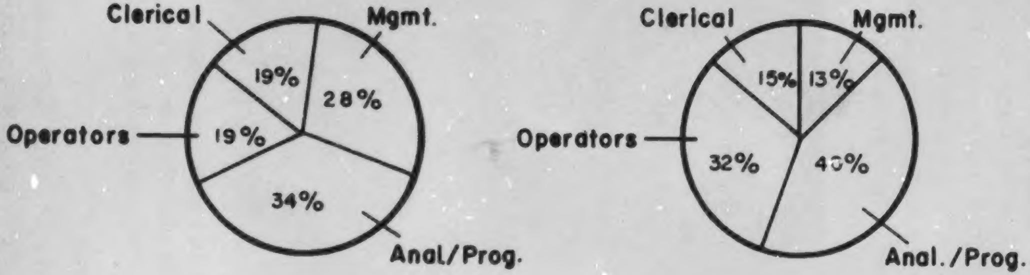
Computers

Among the 112 very large colleges and universities the majority (104) had computers and they operated 349 installations. The fact that less than 100% of the campuses in this category had computing installations probably reflects patterns of remote service to outlying campuses. It is difficult to conceive of any institution of higher education with 20,000 or more students in the United States in 1977 without at least one computer. The very small institutions reported an estimated 19% coverage, which also may be a low figure. Nevertheless, the percentage of very small colleges with computers is quite low.

Computer Science

Colleges with less than 500 students, for all practical purposes, had no degree programs in computer science. According to the 1976-77 inventory, there were only an estimated ten programs—all at the associate degree level. On the large campuses, 56% (129) of the computer science degree programs were at the graduate level (74 master's, 55 doctorate) and 44% at the under-

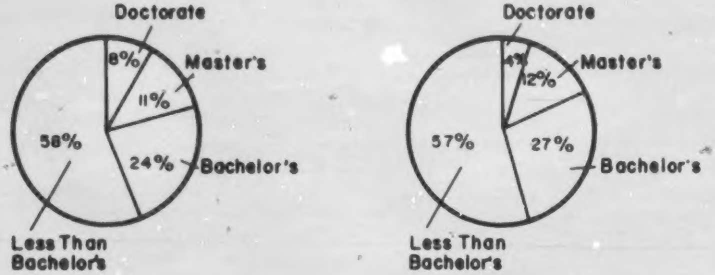
Figure 1.17 A
Proportion of Computer Intallation Staff
by Job Categories and Highest Degree
(Very Small vs. Very Large Institutions)



Very Small
Institutions

Very Large
Institutions

Figure 1.17 B
Proportion of Computer Installation Staff by Job Categories and Highest Degree (Very Small vs. Very Large Institutions)



Very Small Institutions

Very Large Institutions

graduate level (23 associate, 78 bachelor's). However, 72% of the computer science degrees granted were at the undergraduate level, reflecting especially heavy enrollment in bachelor's programs. The number of degrees granted in each category were:

	Very Small	*Very Large*
Associate degree	51	867
Bachelor's degree	—	2,787
Master's degree	—	1,266
Doctorate	—	190

Summary

1. There were six times more colleges with less than 500 students than there were universities with more than 20,000 students, but their total enrollment was only about one-twelfth that of the giants.

2. The very large universities expended $130 per student for their computer installation operations while the very small colleges spent $29 per student.

Table 1.1
Geographic Distribution of Computing Installations

Region[1]	Percent of Institutions Reporting Installations In This Region[2]	Percent of Installations In This Region[2]	Percent of U.S. Population In This Region[1]
North East	7	7	6
Middle Atlantic	16	15	17
East North Central	17	20	19
West North Central	12	12	8
South Atlantic	17	16	16
East South Central	7	6	6
West South Central	8	8	10
Mountain	5	6	5
Pacific	10	10	13

[1] The regional divisions and population data were taken from Statistical Abstract of the United States - 1976, U.S. Dept. of Commerce, Washington, D.C., 1976, p.11.

[2] These data include only the fifty states and Washington, D.C.

3. The educational levels of the computing installation staffs were approximately the same for both classes of institutions, but a higher proportion of managers in the computing staffs of the very small schools reflected the small staff size.

4. Only an estimated 20% of the colleges with less than 500 students had a computer installation. Virtually all very large institutions had computers.

5. For all practical purposes, the very small colleges had no degree programs in computer science. On the very large campuses, over half of the degree programs in computer science were at the graduate level, but almost three-quarters of the degrees awarded were at the undergraduate level.

Regional Differences

Using the regional definitions and population data of the U.S. Department of Commerce, along with the 1976-77 inventory data, it is evident that, in most cases, each region had a proportionate share of institutions with computers and installations. For example, the North East region contained 6% of the total U.S. population while 7% of the institutions reporting installations were in that region. Table 1.1 illustrates this spread.

Two regions which deviated the most from the average are the West North Central region (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota) and the Pacific region (Alaska, California, Hawaii, Oregon, and Washington). In 1977, the former region had 12% of the institutions reporting installations, but only 8% of the population lived within its borders. The Pacific region had 13% of the population within it, but only 10% of the institutions reporting installations.

The six individual states with the highest percentage of institutions reporting installations span the United States. California, New York, and Pennsylvania lead the pack, with Illinois, Ohio, and Texas following at a distance. The percentages of colleges with reported installations relative to the population percentages for these six states are:[1]

	Percent of Institutions Reporting Installations in This State	*Percent of Total U.S. Population in This State*
California	6.9	10
New York	6.8	9
Pennsylvania	6.7	6
Illinois	4.5	5
Ohio	4.3	5
Texas	4.1	6

Summary

1. Colleges and universities with computer installations are well distributed throughout the nation in a pattern quite similar to the population distribution.

2. The actual number of computers (not institutions or installations) was not a part of this evaluation.

Note

1. *Statistical Abstract of the United States – 1976* (Washington, D.C.: U.S. Department of Commerce), p. 11.

2

Computer Systems Changes

Vincent H. Swoyer

This chapter deals with changes in the computing environment on campus, concentrating on hardware and software changes that reflect the relationship between the technological evolution of computing and changes in computers on campus. In Chapter 3 we will look at the service and operational characteristics of the systems described here.

In recent years, the variety of types of systems has caused a branching of technological development and has created a pattern of growth in which several generations of one kind of system mature while another family of systems undergoes slower changes. For simplicity, one may divide the history of academic computer systems into the following periods:

- *First generation:* the period when initial lines of computers were successfully marketed; roughly 1951 through 1960.
- *Second generation:* the period characterized by solid state (transistor) technology; first deliveries of major systems began about 1960.
- *Modern systems:* multiple generations of technology; it isn't clear when one generation or subdivision begins

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and another ends. Characteristics of modern systems include an ability to communicate effectively from remote terminal locations, with the concept of hierarchical storage of data sets, and large amounts of data online in an automated system-controlled environment. Systems with these characteristics began to appear in service environments (as opposed to experimental or development systems) on campuses beginning about 1966.

Early trends in the use of computing hardware, software, physical requirements, and staffing patterns within academic institutions were documented by two series of surveys, both conducted by university- or government-sponsored groups. From 1957 through 1963 a series of six surveys of university computing facilities was conducted by Dr. Thomas Keenan at the University of Rochester.[1-6] These were followed by four inventories of computers in U.S. higher education, conducted by Dr. John Hamblen with National Science Foundation support in 1965, 1967, 1970, and 1977. The interpretive essays in this volume are based on data from the fourth inventory in Hamblen's series.

First Generation Systems

The history of design and construction of digital computers at several well-known universities during the late 1940s reflects faculty interest in producing computing machinery as an engineering challenge as well as a need for mechanized calculators to perform programmed sequences of instructions. However, popular emergence of academic service facilities coincided with the success of vendor-supplied computers in the higher education marketplace. Although a few institutions are willing to invest funds and faculty effort experimenting with computing systems, most colleges and universities have pursued a generally conservative approach to supplying a new computer on campus. The cost of computing equipment has been high, and most institutions have been willing to make significant financial investment only when the risk of an unsatisfactory computer system is very low. As a result, college and university computer center directors have tended toward acquiring commonly accepted systems rather than acquiring untested equipment with possible price-performance advantages.

Early academic computing centers, sampled by the 1956-57 Rochester survey,[7] overwhelmingly chose IBM as vendor. Of twenty-nine responding institutions, twenty-three operated an IBM 650; three of these also operated Univac I, Univac 1101, or Univac 1103 equipment. Other institutions used an LGP-30, a Burroughs 204, an IBM 701, and an Illiac. Thus it appeared that the common choice for an academic computer in the mid-fifties was the computer most popular in the commercial marketplace. Later surveys show that the IBM 650 continued to be the single most popular academic computer through 1960. In terms of scale, the IBM 650 was considered to be mid-range. Larger academic computing facilities, very few in number, employed more powerful systems; the IBM 704 and 709, and Univac 1103 and 1105, were recorded most frequently in first generation surveys. First generation systems tended to tall into two classes: the few large-scale systems (eight of ninety-six installations responding to the Rochester survey series through 1960), and a relatively large number of mid-scale systems (sixty-one from the same group, of which fifty-one were IBM 650s). Estimated average capabilities of these systems, along with some physical and cost statistics are shown in Table 2.1.[8]

The data in Table 2.1 illustrate large- and middle-scale first generation systems. In addition to these systems, which represent about 75% of the first generation facilities, there were a number of small operations labeled as computing centers but with very modest computing capability and little or no staff. Some simply contained calculators or a tabulating machine.

Economy of scale was very apparent in the first generation computers. The internal speed of large systems was at least twenty times that of middle-scale systems, but cost of the larger systems was only five times greater. Smaller systems were also considerably less efficient due to the absence of operating systems. An estimated cost per computation of typical early systems is of interest, but must be taken with a large grain of salt because of the primitive mode of operation. Discussion of oper-

Table 2.1
Common First Generation Academic Computing Systems

	Large-Scale (IBM 704/709, Univac 1103/1105)	Mid-Scale (IBM 650, Burroughs 204/205)
Speed: Additions per second	41,500	1,430
Average memory cycles per second	83,000	417
Memory Size	32,000 36-bit words	2,000 10-digit decimal words
Average Monthly Rental (after educational discount)	$15,000	$3,600
Average Annual Operating Cost of Computing Center	$355,000	$75,000
Average Full-Time Staff	20	7
Average Machine Room Size (Square Feet)	2,600	1,000

ating characteristics will be provided in the next chapter. For the purpose of comparison, we may estimate a *minimum* cost per million computations, which blindly assumes a program to be in execution (ignoring the relatively long time needed to set up each job) for an extended period. This could occur perhaps during a statistical analysis involving a large number of variables, or a converging type of calculation with ill-conditioned data. In these situations a computation (defined as one million arithmetic calculations) on the typical first generation middle-scale computer was valued at about $2.48. On the typical large-scale machine the same computation was valued at twenty-seven cents. (Cost here is based on average reported operating cost, including equipment and supplies, maintenance, and staffing.)

Software was little more than machine language on most first generation systems. The popular IBM 650 could literally be programmed in its machine language, which was fairly easy to use because of the decimal number base of the system. A symbolic assembler language (SOAP) was developed for the IBM 650, mainly to assist with the calculation of address locations to optimize the placement of instructions onto the rotating drum memory. A version of FORTRAN was implemented late in the life of the IBM 650, but was extremely clumsy to use because it required three passes of intermediate card decks to obtain a machine language version which could be executed. On the positive side, however, most early program writers had an excellent understanding of the machine's architecture, and interacted with the computer during the execution with machine language program patches. Seldom does the average programmer of today know such interrelationships of machine code and hardware components, and have the complete working knowledge of computer operation needed to survive with an IBM 650 in the 1950s.

Software on large systems was more advanced. The IBM 704 and successor IBM 709 systems ran user-created operating systems, or monitors, which allowed the user to run a batch of programs in a sequence to make more efficient use of the system. The larger systems were invariably binary computers. Although a significant number of programmers could program in binary code using octal equivalents, coding was so difficult and slow that they were encouraged to develop reasonable assembler languages. By the mid-1950s, an algebraic language called FORTRAN was developed. Today's popularity of the FORTRAN language, nearly twenty-five years later, is a tribute to the group of scientific users who created the original version.

In a nutshell, programming and operating a first generation computer was usually straightforward, but often tedious.

Second Generation Systems

As mentioned earlier, the second generation of computer systems was easily identified by the employment of transistors in place of vacuum tube circuitry. This substitution automatically provided advantages of higher reliability, lower electric power consumption, reduced cooling requirements, and smaller physical size. In addition, the smaller size of physical components reduced circuit lengths, which resulted in faster computation times. The basic architecture generally remained the same; in fact, in the early 1960s a second generation follow-on to a first generation computer frequently used its predecessor's software with little or no changes.

The number of academic computing facilities grew rapidly with the introduction of second generation computers. The large scale IBM 709 computer was replaced by transistorized versions in the IBM 7090/7094/7044 series, and the CDC 1604. These computers were architecturally similar to their first generation predecessors, and used the same programs and operating systems at first. In terms of cost, the IBM 709 (with an average rental of about $15,000 per month after educational discounts) was replaced by the IBM 7090 for a price about 50% higher. The CDC 1604 near-equivalent listed for about 20% less than the IBM 709, and presented an attractive alternative with its more accurate 48-bit word in place of IBM's 36-bit standard. Both the IBM 7090 and CDC 1604 could perform about 225,000 additions per second, roughly five times the speed of the IBM 709. Although the typical second generation large-scale system represented a more costly operation, the cost per computation dropped from twenty-seven cents per million arithmetic calculations (first generation) to about nine cents per million arithmetic calculations.

From a preponderance of the popular mid-scale computing facilities of the first generation, campuses moved in several directions as second generation systems made their IBM 650s obsolete. The number of campus IBM 650s dropped from 39 reported in 1961 to only 7 by 1963.[9] Proponents of decimal-oriented computers were able to migrate to the IBM 7070/7072/7074 series; by 1963 there were 12 of these systems reported in university facilities. But the trend within the second generation academic facilities was apparent. Between 1961 and 1963, the number of second generation machines grew from about 100 to about 300. IBM captured the popular market once again and installed the IBM 1620 in more than 130 colleges and universities. Second place in reported installation frequency was the IBM 1401 with 41 systems installed. However, most of these were used to handle the printing load generated by the 34 IBM 709/7090/7094/7070/7072/7074 installations reported. A characteristic operating mode for the high-priced large-scale computers involved the use of the relatively inexpensive IBM 1401 computer, with its outstanding 1403 high-speed printer. The IBM 1401 would accept the large system's output on magnetic tape, and print or punch the output while the large computer went on with its calculations. As many as three IBM 1401s were used to keep up with the output from one IBM 7094. The CDC 1604 used its companion CDC 160 in a similar fashion.

Table 2.2 provides a tabulation of the characteristics of the most popular small, medium, and large systems in use in 1963.[10]

The cost per million calculations, as with the first generation systems, must be noted to be hypothetical. These costs assume an uninterrupted workload, which under most circumstances could never be achieved. Since they represent consistent measurements, however, the costs present some interesting comparisons between first and second generation machines. We note that the economy of scale still heavily favors the large-scale system. For the first time, however, we see the effect of a low-cost, low-overhead computer offering a lower cost per computation. This phenomenon prevails through many small-scale systems today, and frequently causes certain computing systems to appear to be highly attractive bargains by comparison with larger systems. The capabilities of two kinds of systems may differ greatly, and comparisons based on only one variable, such as simple arithmetic speed, are extremely misleading. All that the cost per computation figure indicates is that one could add together two small numbers many millions of times at a lower cost on a fully staffed (by one person) IBM 1620 than on a fully staffed IBM 7070. No consideration is given for input or output characteristics, memory size or speed, peripheral equipment capabilities, other available operations, or other functional characteristics.

Second generation systems offered more hardware options than had been available on first generation computers; choices were available among printers, card readers, and other on-line devices and disc drives and drums became useful as secondary storage for operating systems and during execution of utility tasks such as sorting. The biggest changes, however, occurred with software; the second generation marked the shift to higher level languages for virtually all applications programming.

Table 2.2
Popular Second Generation Academic Computing Systems

	Large-Scale (IBM 7090)	Mid-Scale (IBM 7070)	Small-Scale (IBM 1620)
Speed: Additions per second	227,300	16,700	1,800
Memory cycles per second	454,600	166,700	50,000
Memory Size	32,000 36-bit words	10,000 10-digit decimal words	20,000 to 100,000 characters
Average Monthly Equipment Cost	$22,200	$15,500	$1,600
Average Annual Operating Cost of Computing Center	$531,000	$372,000	$37,000
Average Full-Time Staff	30	23	1
Average Machine Room Size	2,412	2,039	738
Estimated Total Cost Per Million Arithmetic Calculations	9.4 cents	89 cents	82 cents

FORTRAN, an embryonic language of the first generation, became the universal programming language for scientific calculation on systems of all sizes in the second generation. As FORTRAN became popular, the fraction of computer professionals capable of understanding machine language dropped sharply. Of great significance in the second generation was the emergence of operating system software that enabled large computers to queue up work and continue to run productively from the completion of one job to the beginning of the next without interruption or pause. Finally, the concept of subroutines, small programs which could be called by main programs instead of repeating series of common calculations, became commonplace.

College and university computing centers, not yet overcome by the economist's urge to put a price on everything that is useful, generated many "packages" of programs to perform standard statistical and numerical analyses. As the number of academic computing facilities grew from 100 in 1961, to 300 in 1963, to over 700 by 1965, the free interchange of computer programs changed the approach to analysis of data in all disciplines. Statisticians were no longer restricted to a handful of variables and only a few observations. Social scientists and psychologists began to measure and analyze all sorts of new variables, while physical scientists were able to extend the limits of their calculations as computers became faster and computer memories grew larger.

Vendor competition appeared in the marketplace as colleges and universities realized that Control Data, Univac, and Burroughs computers could offer more speed and size for the dollar than IBM. When General Electric appeared on campus with yet another competitor to the IBM series, Dartmouth College acquired a GE computer. The chairman and a mathematics professor inventively developed a new computer language called BASIC, using much student labor. BASIC was an interactive approach to a FORTRAN-like language that was easy to learn. By the middle 1960s, college and university computer center directors began to believe that IBM computers would someday be replaced by other vendors' equipment at most major computing centers.

Modern Systems

Just as major computer systems were stabilizing with standard second generation computers running smoothly (about five years had passed since the initial second generation computers had hit the market), IBM announced the IBM System/360 in April 1964. This introduction seemed to cause all manufacturers to alter course, and by 1966 many new computers had been announced. The IBM 360 announcement marked the beginning of many series of changes among all equipment vendors. Where most competing computers were once synchronized as comparable to one another's models, the new computing systems marketed beginning with the IBM System/360 became hopelessly impossible to compare. The IBM System/360 started the "family" concept under which an upgrade to one computer could be made with the substitution of a larger model processor. In addition, a modular concept was introduced so that memory units, peripheral disk drives, printers, channels, and other devices could be plugged in to expand an existing system. IBM System/360 components established a set of de facto standards, and by 1969 a new trend of "plug-compatible" offerings were being marketed by other vendors.

Many college and university computing centers in the mid-'60s accepted the opportunity to embark on the new IBM series, and in more than a few cases they became bogged down. For the first time, staff at many top-notch computing centers found themselves bewildered by the new concept of a complex vendor-supplied IBM operating system, called OS. The system was controlled by a very precise and complex language called JCL and embodied a new concept for organizing data into "data sets." CDC, as though responding to IBM, offered the largest and fastest scientific computer around with its CDC 6600 in 1965. Univac introduced its 1108 in 1964 as a single processor, and as a multiprocessor in 1965. Burroughs announced its B6500 in early 1966, and General Electric embellished its 600 series.

While these mid- to large-scale activities were progressing among the major computer manufacturers, a little-known manufacturer of very small computers with flexible input-output capabilities, Digital Equipment Corporation (DEC), began to market its PDP series. These computers, dubbed "minicomputers," boomed in the mid-sixties with DEC's highly successful PDP-8. The PDP-8 is now virtually a classic in the minicomputer industry; it offered highly interactive instructional and research computing by exploiting the Dartmouth-developed BASIC language. In the later sixties, Hewlett-Packard and Data General also marketed highly competitive minicomputers, distinguishing their machines by offering a 16-bit word length as opposed to the PDP-8 12-bit word. By the late sixties and early seventies, new minicomputer models were announced every few months by the "big-three" minicomputer manufacturers. Each new model offered faster speeds, better software, and lower prices. The cycles of new offerings in minicomputers were rapid compared with cycles for full-sized computers as technological changes were quickly introduced into the flexible modular racks that are now characteristic of minicomputers. The increased capabilities of the largest minicomputers overlapped those of some mid-scale computers, especially with respect to input-output logic. Confounding the overlap somewhat, DEC also introduced a larger series of computers in 1967; the PDP-10 was aimed at providing large-scale performance for many operations while offering extensive data communications capabilities. A major competitor to the PDP-10, the Sigma 7, was marketed by Scientific Data Systems (SDS); in 1967 it offered about 50% more computing power than IBM's mid-scale 360 Model 50 at roughly the same cost. The Sigma series computers were later marketed by Xerox, who purchased the SDS Corporation in 1970.

Beginning with the third generation equipment, new major computer systems and minicomputers began to diversify to meet differing needs in different institutions. The availability of lower-cost equipment from DEC, SDS (and Xerox), Hewlett-Packard, and Data General spurred the growth of new college and university computing centers. Large-scale users of IBM computers also reduced costs as plug-compatible memories, tape drives, disk drives, and communications interfaces offered extended performance at prices considerably less than the IBM components that they replaced. Ironically, IBM systems with non-IBM enhancements became less expensive than the traditional competitor products, and other major manufacturers, like CDC, GE, Univac, and Burroughs, were forced to reduce prices of their systems.

In the 1969-70 *Inventory of Computers,*[11] more than 1,600 institutions reported the installation of about 2,000 general purpose computer systems. Typical large-scale systems employed IBM 360 Models 65, 67, and 91; CDC Models 6400, 6500, and 6600; Burroughs B5500 and B6500; Univac 1108; and General Electric Models 635 and 645. The following list shows the distribution of these large-scale systems as reported in the companies' 1969 inventories:

IBM	46
CDC	17
Burroughs	13
Univac	8
GE	5

Most of the large-scale systems used FORTRAN as their bread-and-butter software tool; numerous secondary languages included ALGOL, PL/I, and COBOL. Other languages were developed by institutions to perform locally specialized functions such as list processing or operating software generation. With respect to hardware, large-scale facilities fell typically into two camps: the "number-crunchers," where heavy FORTRAN-oriented processing and extensive floating point arithmetic calculations often found the large CDC computers most suitable; and the more general purpose centers, where substantial data base manipulation and updating was mixed with a less frequent requirement for extensive large-scale arithmetic computation. The latter group generally found IBM equipment to be better suited because IBM offered more extensive data handling functional capabilities. Software for third generation and onward software developed in two primary directions. Standard applications software packages were introduced (most notable within academic institutions was the introduction of SPSS, a statistical analysis package for use by social scientists) and very high speed compilers were introduced that enabled rapid translation from subsets of FORTRAN, COBOL, or PL/I source programs to machine language.

The middle-scale computer systems in universities were dominated by the IBM 360 Models 40, 44, and 50, with 195 installations reported in 1969. In distant second place was CDC, with 28 of its 3000 series systems, followed by DEC with 21 PDP-10s. In general, these middle-scale installations used much of the same software as the large-scale systems, with slower computation speeds.

With the advent of large numbers of smaller computing centers, a majority of academic computing facilities employed a variety of small-scale systems. Most popular in 1969 was the IBM 1130, which frequently provided some administrative computing capability on campus in addition to supporting academic activity. There were 331 IBM 1130s reported by academic institutions in 1969.

Costs, physical requirements, and staffing seemed to stabilize during the late sixties at established academic computing facilities. Annual operating costs reached about one million dollars at typical large-scale facilities (although a few of the largest had considerably higher budgets) and remained fairly constant for most of the next decade. Most growth was attributable to inflationary salary costs. Machine room space, which averaged about 2,500 square feet for large-scale second generation systems and about 2,000 square feet for mid-scale systems, was generally adequate to upgrade through more than ten years of growth. Full-time support staff of twenty-five to thirty, typical of middle-scale and upward in the early sixties, remained about the same size through the seventies (although a functional change occurred, which will be described in the next chapter). Cost per computation plummeted rapidly. By 1970, the typical large-scale IBM facility offered five times the computational speed for the same price as its second generation counterpart. Computational cost comparisons paled to insignificance, however, as new functions of data manipulation and access became available at practical prices for the first time.

The modern generation computer system of the late sixties and early seventies was characterized by more efficient language processors, larger and improved data handling capabilities, and the use of standardized software packages. A new technical breakthrough also occurred at this time—remote access to the central computer. Batch terminals and, later on, interactive terminals at remote sites were able to effectively communicate with the main processor.

Present Day Systems

The computer systems employed in today's academic communities have evolved into a spectrum of computer types. Many campuses employ several different kinds of systems to support different requirements. Institutions with major levels of research have large-scale general-purpose computers of predominately IBM (or IBM-type), CDC, or Univac origin. Patterns of the middle seventies have been extended through today. The highest speed large-scale scientific computer is the CDC 176, although the IBM 3033 multiprocessor system is a competitor. Very few systems of this superprocessor variety exist in academic computing facilities. None were reported in 1976-77 data, since they were announced after the survey was conducted. Large-scale academic computing facilities of today typically house computers of the CDC 6000/CYBER series, Univac/1100 series, or IBM 370/168 type. Generically, with a performance factor spread of about two to three, the "IBM 168 type" computers include the IBM 370 Models 168, 3032, and 3033, and highly competitive computers with nearly identical specifications manufactured by other vendors such as the AMDAHL 470 and the ITEL AS/6. In the late seventies, computer center directors have witnessed the introduction of plug-compatible IBM-type central processors; it is now possible to have an "IBM" computer with no components manufactured by IBM. The modern IBM-type large-scale systems are distinguished from most of the large IBM 360 systems of the early 1970s by the extensive use of virtual memory and much improved communications and data transfer capabilities. Built on the programming logic introduced with the 1964 IBM 360 systems, the newest sysems that are similar to the IBM 370 systems indicate the extent to which refinements of a fifteen-year-old technology can be carried. Virtual memory programming allows very large arrays of data to be considered available at a given time in memory; this is accomplished by very rapid swapping of portions of the data from actual main memory to auxiliary storage devices under the control of an operating system that keeps track of where each data block is actually stored at any moment. Communications capabilities of modern systems permit simultaneous access by several hundred remote users at interactive terminals, as well as interconnection to other remote computers. Operating software is very complex, with part of the operating system often fixed into vendor-supplied hardware modules. Only the most adventurous installation can dare to make modifications to the operating system, for fear that the complex system might "blow up" and fail to run altogether. The hardware is automatically monitored by other self-diagnostic hardware and software that prescribes a remedy or corrects for many kinds of potential hardware failures. On-line data bases have become the order of the day, with software systems to administer the data entry and reporting functions that are sold by equipment vendors and a number of software houses. Mysteriously, FORTRAN continues to be the computer language most used by academic source programs, although many jobs are processed by prepackaged and catalogued systems that simply accept data and produce analyses without any user contact with the program. Large installations find COBOL and PL/I runners-up to FORTRAN as a source language.

Most installations, of course, are not of the large-scale variety. In fact, the computer vendor most represented on campuses today is the Digital Equipment Corporation; 983 of about 3,000 reported campus computers are manufactured by DEC. The major minicomputer manufacturers (DEC, Hewlett-Packard, and Data General) accounted for almost 50% of the computers surveyed in 1976-77, and total minicomputer systems accounted for more than 55% of the computers reported. IBM still dominates the field of major computer vendors with 56% of the systems of this category reported; of this group, CDC is in second place with fewer than 10% of reported installations, closely followed by Univac and Burroughs.

Computing on campus has become a conglomerate activity. Large universities no longer report "the computer" employed, as they did in 1967. A typical response from a large university mentions thirty to fifty computers in use, including two or more large systems and many minicomputers. The DEC PDP-11 minicomputer appears more often than any other computer of any size.

The software language most used on computers of all sizes is FORTRAN, followed by COBOL, BASIC, RPG, and PL/I. With some administrative computing performed at 75% of the university and college installations, COBOL and RPG account for virtually all source programs for administrative applications. BASIC appears almost universally on minicomputers.

During the 1970s a major equipment change occurred as the keypunches that punched the cards used as input in most computer facilities prior to the seventies were replaced by cathode ray tube and typewriter terminals. The use of punched-card decks waned in the past four years, as on-line editing of programs and data became economically feasible. It is of interest to note that, despite nearly two decades of technological changes in computers, the venerable IBM 1403 printer, designed in the late fifties and recloaked in a variety of new cabinets, is still the basic printer of the latest 1979 IBM systems. We will probably see some original 1403 printers in operation in the eighties, a quarter century later.

Overall, the typical modern academic computing facility falls into one of two groups: the full-scale facility, with emphasis on data entry, storage, and manipulation capabilities, and perhaps very high-speed large-memory arithmetic capability; or a minicomputer facility which supports interactive terminal access to a small system with sometimes impressive arithmetic speed but modest data manipulation capabilities. Communication with and between computers has become commonplace.

Future Systems

In the marketplace as a whole, the future direction of computer technology will be influenced by the following changes:

- *Low-cost communications.* The trend to very high-speed long-distance communication via satellite transmissions is clear. The cost for a transmission equivalent to today's telephone line connection will be a small fraction of today's cost. Since relative distance is not a factor with satellite communication, it is reasonable to assume that shared facilities will not be limited by geography.

- *Low-cost solid state storage.* With an attendant improvement in speed and reliability, low-cost solid-state storage is on the horizon. A trend toward more data-base organization has started over the past five years; this will be greatly enhanced by much cheaper, faster, and larger on-line file capability. Combined with low-cost communications, repositories of unique collections of remotely accessed data should become commonplace.
- *Converging technologies.* New developments in four types of computer processing are converging: communications (computer-controlled switching and transmissions, etc.), image processing (transfer of information in digitized form to microfiche, paper, graphics, etc.), word processing (text editing, etc.), and data processing.
- *Mass-produced circuit chips.* These have dramatically reduced the size and cost of logical circuits to the point where many types of computational and logical devices will be attachments to such ordinary devices as telephones, television, thermostats and other control devices, and other new products.

The near-at-hand future systems should reflect major improvements and cost savings in the handling and storage of data, which, in turn, should mean improved administrative systems at academic institutions, improved access to bibliographic information, and improved information distribution systems. As low-cost and long-distance wide band communications become more available, colleges and universities should be able to extend interchange and access to information. Computer systems will probably become more modular, with specialized processors to accommodate particular functions. Thus, computer systems with many linked processors, some of them remotely located, should evolve.

As hardware costs continue to decline relative to other computing expenses, software will become a larger item in a typical college computing facility budget. There is already a trend, led by IBM in many cases, to package software separately from hardware. In many cases, one vendor's hardware seems to be designed to make other vendor's software difficult or less effective to use. In addition, specialized software has become a viable product line in its own right. Academic and nonacademic enterprises are creating new software aimed at solving various classes of major problems in segments of the market interesting to many institutions.

In summary, costs and capabilities of future systems will be constrained more by the software and people associated with systems than by the hardware on which the system is based.

Notes

1. T. A. Keenan, *Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1957).
2. T. A. Keenan, *Second Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1958).
3. T. A. Keenan, *Third Annual Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1959).
4. T. A. Keenan, *Fourth Annual Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report No. 8, 1960).
5. T. A. Keenan, *Fifth Annual Survey of University Computing Activities* (Rochester, N.Y.: University of Rochester Report No. 9, 1961).
6. T. A. Keenan, *Sixth Survey of University Computing Facilities* (Rochester, N.Y.: University of Rochester Report No. 12, 1963).
7. Keenan, *Survey*, 1957.
8. Keenan, *Fourth Annual Survey*.
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3

Computing Center Organization

Vincent H. Swoyer

Historical Background

Chapter 2 traces some of the changes in computer hardware and software, and the choices made by colleges and universities when equipping computing facilities. Within the context of those changes and trends, this chapter will relate the way in which computing centers have been organized over the years.

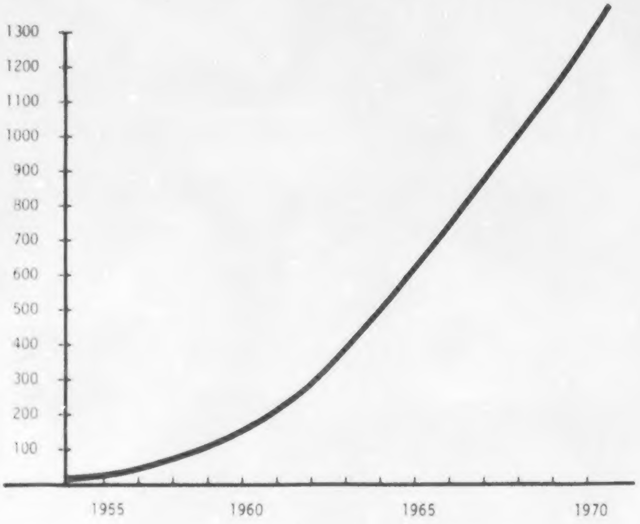
A precise date for the establishment of the first academic computing facility is illusive. It is certain that laboratories dedicated to the support of scientific calculations existed in the thirties, equipped with desk calculators and tabulating equipment of the day. During the forties experimental digital computers were built in a number of laboratories. Although acknowledging the importance of early developments in computer construction, we will concentrate on the organization of computing centers established to provide computing support to academic research and instruction. Service facilities of this type were well established in a number of colleges and universities by the mid-fifties. An early survey[1] shows that of twenty-nine academic computing centers responding to a questionnaire sent to most known facilities, twenty-one indicated that they had been established during the period 1955 through 1957.

The existence of academic computing service facilities has been the subject of a number of surveys. As mentioned in Chapter 2, surveys conducted by the University of Rochester,[2-7] followed by Hamblen's *Inventory of Computers in U.S. Higher*

Education, provide a comparable set of observations about many aspects of computing centers.[8-10] Information derived from these surveys forms the basis for an overview of computing center organizations. Although fewer than 2% of the nation's institutions of higher education offered computing support in 1954, by 1966 a known majority of four-year and graduate study institutions had established computing facilities. Figure 3.1 graphs the growth of academic computing facilities through 1970.

Although Figure 3.1 may reflect somewhat fewer than the actual number of academic computing centers, the pattern clearly indicates the better-than-tenfold increase in number of facilities from 1960 to 1970. One may also say with assurance that the slope of this growth pattern leveled off after 1970; less than a threefold increase in the number of centers from 1970 to 1978 would yield a number of centers equal to 100% of all possible institutions.

Figure 3.1
Number of Known Computing Centers in U.S. Colleges and Universities Growth During 1955–1970 Period



Characteristics of Computing Organizations

Early computing facilities were equipped and staffed in ways that indicate a certain conservatism and a fairly consistent perceived set of institutional needs. Very few large-scale systems were operated, in spite of the significant economy of scale afforded by first generation computers. Although it turned out that most computing systems were inadequate to support their campuses within four years after installation, the mid-range IBM 650 was the popular choice of 80% of the academic facilities established in the mid- to late-fifties.

First Generation, 1950s

A profile of the typical first generation computing center and its organization can be gleaned from early surveys.[11, 12] Operating with an IBM 650, the center employed four full-time staff plus a number of part-time people (usually students who represented the equivalent of two full-time positions). The center director, with a budget of about $90,000, reported to a dean or academic department chairman in most cases. In fact, only three of twenty-nine institutions in 1957 indicated a reporting responsibility to a senior academic officer. In those days it was common for a computing center director to express frustration with the lack of visibility computers had on campus with top administrators. (Ten years later the same group complained that top management was too involved with their decisions.)

The most common form of access to a computer was by means of a reserved block of time during which a user would set up the system and run the program deck he had personally coded and punched. Those who think that batch input systems have been antiquated by modern remote access may be hard pressed to picture an operation which predated even an elementary form of batch environment. Batch systems were not to be found on the typical IBM 650, and did not become commonly available until the early sixties. In place of a computer-regulated system, early academic computing centers trained users in computer operation and programming, then allowed those who were qualified to reserve quarter hour blocks of time and to fend for themselves. In this fashion, as many as forty or fifty users would be accommodated in the course of a good day. Each user would code his program (including an input load sequence to bootstrap his job into memory), punch the card deck, set up the computer dials and control panels for the run, and operate the system. Crude as this may sound, it offered a high level of interaction with a job during execution. Today, program modification and inspection of intermediate results in memory during program execution are very difficult to achieve; such was commonplace in the fifties.

With much of the time of day wasted with set-up time, delays between users, and no-shows, the actual cost per useful computation was very high. Charges for computing were usually assessed by measuring wall-clock time with time-clocks or wristwatches. The average charge for use of an IBM 650 was $70 to $100 per hour for those who could pay, and free for unsponsored use or course-related computing.[13-15]

First generation large-scale users experienced a more rigorous environment because of the relatively high cost and considerably higher speed of computers used. Operators were employed by the computing centers, and they accepted decks of cards to be run in rapid succession. Reasonably standard set-up was established locally, and programs run during prime time would adhere to certain conventions which minimized changes in the system between jobs. As first generation large systems matured, automatic monitors, or operating systems, emerged that assigned some of the housekeeping and operating functions to the computer.

Unlike most middle-scale computing facilities, large computing centers had specially designed large (2,000 to 3,000 square feet) computer machine rooms, often with picture windows through which users and other observers could watch the spinning tapes, blinking lights, and activity around the card readers. With a budget of up to $500,000, the large-scale center employed fifteen to twenty-five full-time staff.

Full-time professional staff for first generation centers typically programmed an assortment of general programs. Often a user would bring in a deck of data cards, punched in a format prescribed in the program write-up, and request that a programmer help set up a run using a prepared process. Common program decks were duplicated many times so that users could have their own copies. Characteristically, the first generation professional staff member analyzed new applications, coded programs, prepared program write-ups, taught, and counseled users.

Second Generation, 1960s

As first generation computing equipment became replaced by second generation equipment in the early sixties, characteristics of computing centers changed. Because of the broader spectrum of second generation equipment, the stereotyped IBM 650 operation was replaced by a wider array of service facilities. As the number of academic computing centers increased into the hundreds, with systems ranging from small IBM 1620s to large CDC 1604s and IBM 7090s, facilities began to take on personalities to reflect different institutional interests. Some centers invested considerable talent developing excellent tested program libraries. Other facilities chose to import most programs, which were distributed without charge by the authoring facilities via punched card decks mailed in special brown cardboard boxes. In most cases, centers hired programmers who assisted users with program modifications, mathematical analysis, or special program writing. Computer user groups were also formed as associations of individuals from computing facilities with common sets of equipment from a given vendor.

Irrespective of size, academic computing centers through the second generation were centralized facilities, offering computing, programs, and technical assistance on the use of "the computer." Small-scale computing facilities, with a statistically average size staff of one full-time professional, operated with budgets averaging $30,000 to $40,000. Students provided the majority of small-center staffing. Middle-scale facilities grew in size and budget during the second generation, with staff sizes of twenty or more, similar to first generation large facilities, and budgets in excess of $300,000 per year. Computers in this category required computer rooms of 1,000 to 2,000 square feet. Large-scale facilities, operating with budgets in excess of

$500,000 and more than twenty-five full-time staff, continued to be most cost-effective but still represented a minority of computing centers.[16]

Operating systems became highly refined on mid-scale and larger facilities. Batch monitors were capable of executing commands from control cards which automatically called appropriate software systems and handled input and output with a high degree of efficiency. Hundreds of computer jobs per day churned through the facilities using middle-scale and larger systems, with the difference between the two types largely related to scope of job that could be accommodated.

The function of professional staff changed as specialists began to emerge. Systems programmers concentrated programming efforts on the writing and maintaining of compilers and operating systems, while applications programmers, with subspecialties in such areas as statistics, mathematics, or graphics, focused on the development and testing of programs in their own areas. User communities grew to be very large on many campuses, and many users became very proficient in writing their own programs or using the vast array of library programs. FORTRAN had matured as the universal academic language and was available on most computers.

Institutional computing facilities increased in number very rapidly during the second generation of equipment (roughly through 1966). Contributing to this growth were a number of pressures, including academic competition—colleges and universities sought a special pride that accompanied housing a computer. It was also often a matter of necessity, as faculty in certain disciplines realized a need for computer access in order to keep up with their peers elsewhere. At a significant number of institutions computer centers partially covered costs with government funds; in particular, National Science Foundation programs provided direct support for the acquisition of new computing equipment. In addition, the unit cost of computing decreased as the technology progressed.

A new form of facility became dominant at colleges during the second generation; the "mixed" installation combined administrative and academic computing in a single facility. Of nearly 900 institutional computing facilities responding to the

1966-67 survey, 53% combined academic and administrative activities. In the same survey, 19% were solely academic, and 12% were purely administrative.[17]

Mixed facilities in 1967 typically reported to the chief business officer, although reporting to the top academic officer was also common. The academic head was the person to whom most academic facilities reported. This pattern reflected a dramatic trend toward a most senior reporting level, a change from the pattern of reporting to an academic department head seen ten years earlier.

The combination of academic and administrative work on one computer led to a degree of contention for a valuable resource. However, despite this disadvantage, academic computer users typically acknowledged a need for administrative computer demand to justify the existence of any computer at all. To support the combined workload, computer center directors took one of two approaches. With one approach, a combined staff of operational and professional individuals shared administrative and academic support functions. More commonly, however, the professional group was divided between those supporting administrative work and those supporting academic activities. This split became most apparent as higher level languages diverged, using FORTRAN for academic work and COBOL for administrative work.

Third Generation and Beyond

Characteristic of computing centers through the middle sixties was the notion of consolidated activity. Staffing, training, funding, and equipping were all centralized, both in thought and physical layout, at most institutions. However, in the late sixties, technology and personalities of academic computing facilities began to tend toward a decentralization at many institutions. Space for a large main frame was frequently tight in the main hub of academic activity, and remote reader/printer stations began to appear, with the central processor located in a distant corner or off campus. In addition, individual departments discovered that they could afford their own computers, and many acquired them to gain advantages of control or lower cost not enjoyed when buying service from a general facility.

A follow-on study to the 1969-70 *Inventory of Computers,*[18] conducted by this writer, disclosed that many large institutions had substantial secondary computing facilities, many of which escaped the record of the 1969 inventory. There were many more than the 1,308 installations reported, especially within large institutions. By 1970, an abundance of secondary computers existed on campus for a number of reasons. Some of the justifications were:

- Older computers had become cast off by computing centers, local businesses, or government. These were then used to provide inexpensive computing, and offered an opportunity to experiment freely or make low-cost use of a less reliable system.
- An activity could make efficient use of a more specialized computer to carry out a unique function, such as data collection, or experimental control.
- The requirements of a given group were homogeneous, and required little or no software expense to fully utilize a less expensive computer.

Most institutions in 1970 considered one computing facility to be the general service system. This facility most often reported to the president or other chief academic officer. Major systems, more often than not, accommodated remote terminals from several parts of campus. The notion of interinstitution sharing of a common facility was discussed, but only rarely did this become a reality. However, many colleges used telephone lines to obtain interactive time-sharing services in the late sixties. Institutions within sufficient demands to justify an in-house computer installed keyboard terminals which accessed remote commercial or academic computers. Most commonly, these terminals supported BASIC programming, with on-line file space for programs or data. Of the 2,103 institutions reporting in 1969-70, 275 indicated that they provided interactive computing services, while 345 indicated that they were users of interactive computing services.[19]

Levels of support staff at college computer centers varies considerably, ranging from zero at many small facilities to about

100 full-time staff at large institutions. The thirty-eight institutions (student population over 20,000) reported an average installation staff size of about 30 people. Since this included all installations, and each institution averaged more than three computing installations, it is apparent that the primary computing facility at a large institution was much larger. The composition of full-time staff was roughly one-third management and clerical, one-third operators, and one-third programmers and analysts. Middle-range institutions (such as the more than 400 reporting institutions in the 2,500 to 10,000 student bracket) averaged about 12 full-time staff per installation. In this category, the number of computing installations reported was barely 20% more than the number of institutions, indicating that most institutions reported only one computing facility. The division of staff among operators, programmers and analysts, and others was approximately equal, as with the largest institutions. Institutions in the 500 to 2,500 student range were the largest reporting group in 1970, numbering more than 1,000. Of these, 400 reported having one computer installation; no schools in this category reported more than one installation. Average full-time staff at these centers was four, including two operators.

A basic conclusion from the above samples is that the level of support service varied from very little professional assistance for users in the majority of installations, to a fairly large professional staff at the largest few dozen institutions. A dependence on outside software sources was apparent at most computing facilities by the early seventies.

About 1970, another kind of academic computing facility began to appear; this was the small service center based on a minicomputer. Minicomputers were used widely as control devices and in specialized application during the late sixties, but were not used for general computing support at academic institutions in any numbers before 1970. The risks and necessary investment in time were relatively high during the early days of general purpose minicomputers, although the costs were often lower than the full cost of even one time-sharing terminal. The desire to have a computer on campus, aided by reports in the early seventies from a successful NSF-sponsored experiment which showed that minicomputers placed in an inexperienced academic environment could supply effective support for academic computing at very low cost,[20] led many institutions to install minicomputer systems. Most of these facilities used time-sharing terminal access, and supported anywhere from one to about thirty terminals on a single system. Because of standardized software, typically no more than two full-time people (and frequently none) were required to run a minicomputer facility.

By 1977, when the fourth inventory of computers was conducted, the variety of computing center organizations present in colleges broadened considerably. From 1970 to 1977 considerable technological growth led to a dramatic decrease in unit cost for computers, especially for smaller computers, during an otherwise inflationary economic period. This cost decrease, in turn, led to a greater variety in computing hardware and service than had previously been possible in colleges.

The largest university computing centers have generally upgraded facilities around a central large processor, with a combination of a few remote batch terminals and many interactive terminals communicating with the system. On large university campuses, user groups composed of faculty and research assistants frequently operate one or more computer systems that perform data reduction or smaller-scale analysis before transmitting data to the central computing facility. In some cases, a requirement for arithmetic capacity beyond the scope of the general facility has dictated a need for a department facility with larger-scale computing capability.

At the other end of the spectrum, a new smaller version of the minicomputer, the very low-cost microprocessor, has emerged. At large universities hundreds of microprocessors are present on campus, often without the knowledge or supervision of the central computing staff. The cost of a microprocessor-based system is so low that a well-heeled student can literally buy his or her own, and have in a dormitory room a computing capability that easily overshadows many institutional systems of the first generation. Obviously, organization of computing on campus has changed.

The support staff required in today's college computing environment is frequently a group that brings together the expertise needed to modify or develop a variety of software as well as interface all kinds of computing equipment with a variety of terminals, communications devices, and on-line storage media.

Computing professionals must examine an ever increasing amount of new material as the computing, communications, library, and image graphics technologies converge. A number of institutions have elected to create new senior management positions which reflect combinations of responsibilities in these areas. Forty-eight installations responding to the 1977 inventory indicate that the head reports to a "Computer Czar" type of position. As might be expected, most institutions with this office are in the two largest enrollment groups.

Another new phenomenon of the seventies is the employment of facilities management groups; this involves an arrangement whereby the management of a college computer facility is performed by an outside professional group. Responses indicate that fewer than 1% of the installations reporting in 1977 used a facilities management group. Unfortunately, data are not available to indicate the history of experience with outside management groups.

Total dollars spent for computing have not increased in real terms on the average between 1970 and 1977 at universities in the largest enrollment category since 1970, although the contribution of federal support has dropped significantly. Table 3.1 displays data on which these patterns are based. Among the largest institutions reporting computing installations, those with more than 20,000 students, reported an average $2.1 million expended on computing in 1970, of which an average $491,000 was supported by federal funds. In 1977, these institutions had increased average computing expenditures to almost $2.8 million, while average federal support fell to only $240,000 in 1977. This reflects a drop from roughly 23% to less than 9% federal support. The next largest group, those with 10,000 to 19,999 students, reported an average expenditure of $919,000 in 1970, of which $165,000 was federally supported. In 1977, this group reflected a slight decrease in total average computing expenses to $902,000, of which federal support levels dropped

Table 3.1
Trends in Support for Computing 1970-77

	Total Number of Institutions Reporting Installations	Sources of Income		Averages		% Support From Federal
		Total $ Expended	Federal $ Support	Total Expended Per Institution	Federal Support Per Institution	
1970 20,000 & Above	39	83,544K	19,161K	2,142K	491K	22.94%
1970 10,000 to 19,999	113	103,856K	18,644K	919K	165K	17.95%
1977 20,000 & Above	72	197,259K	17,306K	2,740K	240K	8.76%
1977 10,000 to 19,999	121	109,153K	8,348K	902K	69K	7.6%

from about 18% in 1970 to less than 8%. Unless a reversal in the trend of federal support occurs, the indication from the above groups (which traditionally receive the greatest average federal support for research activity) indicates that almost all computing on campus will have to be self-sustained.

During the same time period 1970-77, the amount of computing obtained per institutional dollar has increased considerably, with or without external support. This trend is certain to continue, as new technological developments enable even more cost-effective use of memory and communications. It appears that hardware technology development will create ever increasing diversity of computing installations. The attending growth of complexity in software requirements, however, coupled with a trend toward more sales of prepackaged programs, indicates a need for coordinated software development, instruction, and investment. The trend in computing center organization is less clear. It would appear wise for college personnel to examine the way that all information resources are organized within an institution, and then proceed along a path that will simultaneously further the computing, communications, word processing, information retrieval, and other information handling functions. Networks of information services and access to special archives will be upon us very soon as the cost of communication drops with new satellite developments.

Vendors appear to be moving toward providing more prepackaged software so that total function, rather than hardware and software potential, will be available to college computer centers with little on-campus systems expertise required. Common carrier telephone companies will probably move to provide cheaper communications in response to the activities of information handling vendors. The net result of these changes will probably be a move away from software development and support at most campuses. Instead, campus computing staffs will probably devote most effort to helping users locate information sources, evaluate new information devices (displays, storage devices, data collection devices, etc.) to maintain compatibility with existing systems, and make the best use of a changing information systems environment.

Notes

1. T. A. Keenan, *Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1957).

2. Ibid.

3. T. A. Keenan, *Second Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1958).

4. T. A. Keenan, *Third Annual Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report, 1959).

5. T. A. Keenan, *Fourth Annual Survey of University Computing Centers* (Rochester, N.Y.: University of Rochester Report No. 8, 1960).

6. T. A. Keenan, *Fifth Annual Survey of University Computing Activities* (Rochester, N.Y.: University of Rochester Report No. 9, 1961).

7. T. A. Keenan, *Sixth Survey of University Computing Facilities* (Rochester, N.Y.: University of Rochester Report No. 12, 1963).

8. John W. Hamblen, *Computers in Higher Education: Expenditures, Sources of Funds and Utilization for Research and Instruction 1964-65, with Projections for 1968-69* (Atlanta: Southern Regional Education Board, 1967).

9. John W. Hamblen, *Inventory of Computers in U.S. Higher Education, 1966-67* (Washington, D.C.: U.S. Government Printing Office, 1970).

10. John W. Hamblen, *Inventory of Computers in U.S. Higher Education, 1969-70* (Washington, D.C.: U.S. Government Printing Office, 1972).

11. Keenan, *Survey*, 1957.

12. Keenan, *Second Survey.*

13. Keenan, *Survey*, 1957.

14. Keenan, *Second Survey.*

15. Keenan, *Third Annual Survey.*

16. Keenan, *Sixth Survey.*

17. Hamblen, *Inventory of Computers, 1966-67.*

18. Hamblen, *Inventory of Computers, 1969-70.*

19. Ibid.

20. Vincent H. Swoyer, *Use of Minicomputer Facilities for Higher Education Instruction* (Atlanta: Southern Regional Education Board, 1975).

4

Administrative Uses of Computers in Higher Education

Charles R. Thomas

Introduction

History

Administrative data processing in higher education began in the 1940s when business officers and registrars started utilizing punched-card equipment and ledger-card machines to perform record-keeping tasks. In the following two decades, the use of punched-card equipment for administrative applications grew steadily. During the same two decades many colleges and universities began using computers for research projects in scientific academic areas. Since many of the first generation computers utilized punched cards for input and output, there were isolated instances of the use of these computers for administrative tasks.

Concerted efforts to use computers for administrative data processing began in the early 1960s when many colleges and universities converted record-keeping systems from punched card tabulating equipment to second generation computers which had improved magnetic tape storage and file handling techniques. The availability of the new computer processing techniques for administrative tasks came at the same time as the enrollment in-

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creases of the 1960s, providing administrators with the tools to handle the increased paperwork associated with the enrollment boom. Although the second generation computers were general purpose, most administrative applications were designed to operate as high-speed tabulating machines using sequential files converted directly from punched cards to magnetic tape or disk storage.

Some of the early administrative applications used scientific computers on an off-shift or shared priority basis. To avoid priority conflict issues, some institutions set up separate administrative computing installations. In other cases separate administrative computing installations grew out of the tabulating shops which were generally under the control of the business office. Today the control of a computing installation in large measure depends upon the history of administrative computing in a particular college; in turn, control determines which applications are developed first as well as which department receives priority for production processing.

Sophisticated data-handling techniques involving other than sequential files were not generally used for administrative applications until the mid-1960s when third generation computers were installed in a sizable number of institutions. Reliable mass storage devices and direct access software, available in the late 1960s, made it possible to develop more sophisticated administrative applications. The titles of papers presented at the College and University Machine Records Conferences over the years trace the evolution of administrative systems design from the early tabulating approaches to the current state of the art.

Previous Survey Results

The 1966-67 *Inventory of Computers in U.S. Higher Education*[1] included a section on administrative uses that listed sixty-nine applications in five major administrative areas. Intervening surveys did not include a section on administrative uses until 1976-77. When the administrative applications listed on the 1966-67 survey forms are compared to the 126 applications and 11 major areas listed on the 1976-77 survey form, only 51 of the items listed on the earlier form qualify as comparable applications; the others are programs within an application. This comparison indicates that in the ten years between the two surveys the administrative use of computers more than doubled, both in terms of the number of administrative areas served and the number of applications within those areas.

Since only thirty-five institutions reported administrative uses of computers in the 1966-67 survey, no real comparison can be made with the 1,822 respondents to the 1976-77 survey. One can note that there was a very large increase in the administrative use of computers in colleges in the decade between the two surveys. Almost all usage reported in 1966-67 was batch processing; on-line usage in 1976-77, at the aggregate level, represented 15% of the usage reported. It can also be assumed that a great deal of the administrative data processing was unreported in 1966-67, since at that time many administrative data processing units were separate from the computing installations responding to the survey.

Current State of the Art

Several analyses of the 1976-77 summaries of the responses to *Form 4: Institutional Administrative Applications* are shown in the charts included at the end of this chapter. Table 4.1 indicates that the use of the computer is most prevalent in the admissions and records area, followed by financial management, with planning, management and institutional research applications third. Physical plant operations have the lowest reported utilization except for the hospital area, which few institutions reported.

The one administrative application reported by the highest number of institutions was class rosters in the admissions and records area. This information is consistent with a previous survey[2] conducted by the National Center for Higher Education Management Systems (NCHEMS) which indicated that admissions and records and financial systems used the most computer resources, and physical plant operations used the least.

The percentage of applications reported as operating in an on-line mode was 15% across all administrative areas and for all reporting institutions. The on-line application percentages by major administrative area ranged from a low of 10% in the general administrative service and the physical plant areas to a high

Table 4.1
Administrative Applications by Institutional Control

Major Administrative Application Area	All Institutions	Public Institutions	Private Institutions
All Areas	41,637 (22.8)	28,432 (32.4)	13,205 (14.0)
Planning, Management & Inst. Research	5,689 (3.1)	4,157 (4.7)	1,532 (1.6)
Financial Management	10,008 (5.5)	6,544 (7.5)	3,464 (3.7)
General Administrative Service	2,838 (1.6)	2,286 (2.6)	552 (0.6)
Auxiliary Service	1,872 (1.0)	1,136 (1.3)	736 (0.8)
Logistics & Related Services	1,941 (1.1)	1,549 (1.8)	392 (0.4)
Physical Plant Operations	770 (0.4)	528 (0.6)	242 (0.3)
Admissions & Records	12,846 (7.7)	8,522 (9.7)	4,324 (4.6)
Financial Aid	1,537 (0.8)	973 (1.1)	564 (0.6)
Library	1,497 (0.8)	1,033 (1.2)	464 (0.5)
Other Administrative	2,190 (1.2)	1,377 (1.6)	813 (0.9)
Hospital	449 (0.2)	327 (0.4)	122 (0.1)
Number of Institutions	1,822	877	945

This chart shows the number of batch-processing and on-line administrative computer applications reported in each of the eleven major administrative areas for all institutions and by institutional control. The average number of applications per institution for each cell of the matrix appears in parentheses below each total to provide a relative measure between categories. The number of institutions reporting in each category appears at the bottom of the chart.

of 40% and 41% in the library and hospital areas. The admissions and records area had the highest reported on-line percentage of the three major administrative areas (financial management, admissions and records, and planning). Table 4.2 shows the percentage of applications reported as operating in an on-line mode for the eleven administrative areas.

The high percentage of on-line processing reported in the library and hospital areas, coupled with the small number of institutions reporting the use of computers in these areas, indicates that the use of computers in these areas is just beginning. Also, the libraries and hospitals are starting with a more current technology. This same phenonema also accounts for the higher percentage of on-line systems reported by private institutions and by smaller institutions; these institutions have the advantage of state of the art technology although they are obtaining computers for the first time.

Administrative Uses by Institutional Categories

Summaries of the responses to *Form 4: Institutional Administrative Applications* were analyzed by institutional control, level, and size to determine the difference in the utilization of computers among the various categories. The charts included at the end of this chapter provide the details of these analyses; however, some of the general differences are highlighted in the following paragraphs.

Analyses by Institutional Control

In general, public institutions report a higher level of computer utilization for administrative purposes than private institutions. However, the private institutions report a higher percentage of their systems operating in an on-line mode. The level of usage reported by public institutions is almost double that of the private institutions in most major administrative areas, and almost triple in three of the eleven areas: planning, management and institutional research; general administrative; and logistics and related services. The one application that public and private institutions report at an almost equal level is alumni records.

As noted earlier, private institutions consistently report a

Table 4.2
Percentage of Applications Reported On-Line

Major Administrative Application Area	All Inst.	Control		Degree Level				Institution Size*				
		Publ.	Priv.	Doct.	Mast.	Bach.	Asoc.	A.	B	C	D	E
All Areas	15%	14%	17%	16%	15%	12%	15%	27	15%	14%	14%	17%
Planning, Management & Inst. Research	12%	11%	16%	14%	13%	12%	11%	28%	14%	11%	10%	13%
Financial Management	12%	12%	12%	12%	13%	8%	15%	22%	13%	11%	11%	13%
General Administrative Service	10%	9%	13%	12%	12%	6%	8%	38%	9%	9%	11%	11%
Auxiliary Service	13%	10%	17%	13%	15%	12%	7%	44%	16%	9%	9%	16%
Logistics & Related Services	14%	14%	16%	18%	12%	5%	15%	32%	12%	12%	15%	23%
Physical Plant Operations	10%	9%	10%	9%	10%	3%	14%	24%	11%	9%	2%	12%
Admissions & Records	16%	16%	18%	16%	16%	14%	19%	25%	15%	17%	15%	18%
Financial Aid	14%	12%	16%	16%	13%	11%	14%	44%	15%	10%	16%	16%
Library	40%	32%	59%	40%	42%	51%	27%	70%	50%	34%	41%	36%
Other Administrative	12%	9%	16%	14%	11%	12%	10%	24%	14%	10%	7%	14%
Hospital	41%	47%	25%	-	-	-	-	-	-	-	-	-

This chart shows the percentage of administrative computer applications reported operating in an on-line mode in each of the eleven major administrative areas. Percentages are shown in all areas for the total group, by institution control, degree level, and by institution size.

* Institution Size: A=<500, B=500-2499, C=2500-9999, D=10,000-19,999, E=>20,000

higher percent of their systems operating in an on-line mode in all major administrative areas except for the hospital area, where public institutions report 47% of their systems operating on-line as compared to 25% for private institutions. Of significant interest is the fact that private institutions report 59% of their library systems operating on-line and public institutions report only 32% on-line.

The only area in which public and private institutions report an equal percentage of on-line systems is financial management; this occurs primarily because the fiscal systems are traditionally batch-processing systems in all types of institutions.

Recall that Table 4.1 shows the rank ordering of the eleven major administrative areas for public and private institutions based on the number of batch and on-line computer systems reported in each area. While admissions and records, financial management, and planning, management and institutional research are listed first by both public and private institutions, alumni records, auxiliary services, and financial aid administration applications are reported with a higher frequency by private institutions than by public institutions. This reporting indicates that, beyond the first three major administrative areas, private institutions automate the functions dealing with students, faculty, and alumni more often than the general administrative and logistical service functions, while the reverse is true in public institutions.

Analyses by Institutional Degree Level

Analyses by institutional degree level indicate that as institutional complexity increases, both the number of computer applications and the percentage of on-line applications increase, with one exception: the associate degree level institutions generally report slightly more applications and a slightly higher percentage of on-line systems than the bachelor's level institutions. Again, a later start at a higher level of technology may account for this phenomenon. A rank ordering of the applications based on the frequency of reporting within the major administrative areas shows no significant difference among the four degree levels. The three highest and the lowest reported applications in each area are essentially the same at each degree level for all institutions. See Table 4.3 for details of this analysis.

Analyses by Institutional Size

The analyses by institutional size shown in Table 4.4 indicate that, as the size of the institution increases, the number of applications per institution increases from a low of about 3 applications of the 126 possible for institutions with less than 500 students to a high of almost 60 for institutions with over 20,000 students.

Tables 4.4 and 4.5 show that the smallest institutions report very few administrative applications, however Table 4.2 shows that those same small institutions report a much higher percentage of on-line applications. Several factors can account for this situation. First, as mentioned before, the smaller schools started using computers more recently, so they were able to start at a higher level of technology. Also, the small sizes of the data files make it easier to have all institutional data available on direct access storage media for on-line access. In addition, institutions that recently began using computers for administrative purposes do not have the burden of converting many large and complex batch-processing systems to the on-line mode. Many larger institutions that developed large applications on second generation computers are still operating second generation batch systems in most of the traditional application areas. The small number of applications reported by small institutions also indicates that little integration of new systems with older systems is required, making it easier to implement a few new systems in an on-line mode.

Administrative Uses by Application Areas

The eleven major administrative computer application areas noted in Table 4.1 roughly parallel the Institutional Support Program (6.0) of the *Program Classification Structure*[3] published by the National Center for Higher Education Management Systems. Charts 4.1 through 4.12 show the rank order of applications based on the total of the batch processing and on-line computer applications reported by public and private institutions in each application area. Charts 4.13 through 4.16 show

Table 4.3
Administrative Applications by Institutional Degree Level

Major Administrative Application Area	All Instns.	Doctorate	Masters	Bachelors	Associate
All Areas	41,637 (22.8)	11,813 (41.6)	11,489 (27.2)	6,770 (14.7)	11,565 (17.7)
Planning, Management & Inst. Research	5,689 (3.1)	1,588 (5.6)	1,581 (3.7)	812 (1.8)	1,708 (2.6)
Financial Management	10,008 (5.5)	2,827 (10.0)	2,735 (6.5)	1,732 (3.8)	2,713 (4.1)
General Administration Service	2,838 (1.6)	905 (3.2)	735 (1.7)	363 (0.8)	835 (1.3)
Auxiliary Service	1,872 (1.0)	624 (2.2)	607 (1.4)	350 (0.8)	291 (0.4)
Logistics & Related Services	1,941 (1.1)	662 (2.3)	435 (1.0)	211 (0.5)	633 (1.0)
Physical Plant Operations	770 (0.4)	277 (1.0)	168 (0.4)	117 (0.3)	208 (0.3)
Admissions & Records	12,846 (7.7)	2,901 (10.2)	3,614 (8.6)	2,265 (4.9)	4,066 (6.2)
Financial Aid	1,537 (0.8)	440 (1.5)	460 (1.1)	283 (0.6)	354 (0.5)
Library	1,497 (0.8)	563 (2.0)	423 (1.0)	235 (0.5)	276 (0.4)
Other Administrative	2,190 (1.2)	651 (2.3)	674 (1.6)	397 (0.9)	468 (0.7)
Hospital	449 (0.2)	375 (1.3)	57 (0.1)	4 (0.0)	13 (0.0)
Number of Institutions	1,822	284	422	461	655

This chart shows the number of batch-processing and on-line administrative computer applications reported in each of the eleven major administrative areas for all institutions and by institutional degree level. The average number of applications per institution for each cell of the matrix appears in parentheses below each total to provide a relative measure between categories. The number of institutions reporting in each category appears at the bottom of the chart.

Table 4.4
Administrative Applications by Institutional Size

Major Administrative Application Area	All Instns	Less Than 500	500 to 2,499	2,500 to 9,999	10,000 to 19,999	20,000 and Over
All Areas	41,637 (22.8)	952 (2.4)	13,309 (17.1)	16,907 (38.2)	5,912 (45.1)	4,557 (59.2)
Planning, Management & Inst. Research	5,689 (3.1)	134 (0.3)	1,563 (2.0)	2,431 (5.5)	873 (6.7)	688 (8.9)
Financial Management	10,008 (5.5)	283 (0.7)	3,444 (4.4)	3,959 (8.9)	1,310 (10.0)	1,012 (13.1)
General Administration Service	2,838 (1.6)	56 (0.1)	692 (0.9)	1,214 (2.7)	503 (3.8)	373 (4.8)
Auxiliary Service	1,872 (1.0)	34 (0.1)	570 (0.7)	790 (1.8)	253 (1.9)	225 (2.9)
Logistics & Related Services	1,941 (1.1)	41 (0.1)	475 (0.6)	785 (1.8)	347 (2.6)	293 (3.8)
Physical Plant Operations	770 (0.4)	25 (0.1)	261 (0.3)	260 (0.6)	107 (0.8)	117 (1.5)
Admissions & Records	12,846 (7.1)	264 (0.7)	4,565 (5.9)	5,314 (12.0)	1,619 (12.4)	1,084 (14.1)
Financial Aid	1,537 (0.8)	32 (0.1)	494 (0.6)	612 (1.4)	239 (1.8)	160 (2.1)
Library	1,497 (0.8)	20 (0.1)	398 (0.5)	576 (1.3)	274 (2.1)	229 (3.0)
Other Administrative	2,190 (1.2)	38 (0.1)	701 (0.9)	892 (2.0)	314 (2.4)	245 (3.2)
Hospital	449 (0.2)	25 (0.1)	146 (0.2)	74 (0.2)	73 (0.6)	131 (1.7)
Number of Institutions	1,822	392	779	443	131	77

This chart shows the number of batch-processing and on-line administrative computer applications reported in each of the eleven major administrative areas for all institutions and by institutional size. The average number of applications per institution for each cell of the matrix appears in parentheses below each total to provide a relative measure between categories. The number of institutions reporting in each category appears at the bottom of the chart.

Table 4.5
Highest Percentage of Institutions Reporting at Least One Application

Major Administrative Application Area	All Inst.	Control		Degree Level				Institution Size*				
		Publ.	Priv.	Doct.	Mast.	Bach.	Asoc.	A	B	C	D	E
All Areas	53%	70%	37%	70%	61%	43%	49%	8%	50%	86%	82%	88%
Planning, Management & Inst. Research	31%	48%	17%	55%	40%	17%	28%	5%	22%	58%	65%	82%
Financial Management	48%	62%	36%	70%	55%	39%	41%	8%	46%	74%	73%	88%
General Administrative Service	27%	46%	14%	56%	32%	14%	24%	3%	17%	49%	66%	78%
Auxiliary Service	33%	41%	25%	58%	46%	27%	17%	3%	27%	57%	55%	69%
Logistics & Related Services	26%	46%	12%	45%	26%	11%	28%	3%	17%	46%	55%	64%
Physical Plant Operations	18%	24%	13%	41%	19%	13%	12%	3%	16%	25%	32%	53%
Admissions and Records	53%	70%	37%	64%	61%	43%	49%	7%	50%	86%	82%	87%
Financial Aid	26%	34%	18%	41%	35%	18%	20%	3%	20%	44%	54%	62%
Library	16%	21%	12%	37%	19%	13%	8%	2%	12%	23%	37%	51%
Other Administrative	35%	39%	31%	61%	50%	33%	21%	4%	32%	53%	60%	71%
Hospital	4%	5%	2%	19%	3%	1%	1%	1%	3%	3%	8%	19%
Number of Institutions	1822	877	945	284	422	461	655	392	779	443	131	77

This chart shows the highest percentage of Institutions reporting at least one administrative computer application in each of the eleven major administrative areas. Percentages are shown for all areas for the total group, by institution control, degree level, and by institution size. The number of institutions reporting in each category is shown at the bottom of the chart.

* Institution Size: A=<500, B=500-2499, C=2500-9999, D=10,000-19,999, E=>20,000

similar information by institutional degree level and by institution size. However, only the three most reported applications and the least reported application are shown for each major area. The charts are included at the end of this chapter. Specific comments for each major application area follow.

Planning, management and institutional research applications as a group are the third highest reported group of applications by all categories of institutions. Public institutions report almost three times as many applications per institution in this category as do private institutions, and the number of applications reported increases with institutional degree level and with institutional size.

Budget related applications are reported most often by private institutions and by the small institutions, while HEGIS (Higher Education General Information Survey) reporting is listed most frequently by public institutions and by all degree levels except the doctorate level institutions. Long-range planning is the one application least reported by institutions in most of the categories. This is understandable, however, since most long-range planning activities rely on the output of other computer applications instead of specific systems.

The percentage of on-line applications reported in this area is slightly below the percentage reported by all institutions in all categories except the smallest institutional size category (less than 500 students), where the number of applications is quite low, but the percentage reported operating in an on-line mode is higher than average.

Financial management applications are the second most often reported applications by all institutional categories. Within this area payroll and departmental expenditure accounting are the most reported applications by institutions in all categories. As might be expected, research proposal monitoring is the least reported application by institutions in all categories except the doctorate level and the largest institutions. Financial management applications dealing with students are generally more often reported by private institutions than public institutions, except for financial aid accounting, which ranks higher in public institutions than in private institutions.

The percentage of on-line applications reported in the financial management area is relatively stable across all categories, and is slightly below the average of all the application areas.

General administrative service applications rank fourth in reporting frequency by public institutions and seventh by private institutions. Within the application area, private institutions report personnel records systems more often than systems dealing with facilities, while public institutions report facilities related systems more often than personnel records. The doctorate and master's level institutions also report personnel records systems more often than facilities related systems, and the bachelor's and associate level institutions report the reverse. The rankings by institution size do not follow any discernable pattern; however, institutions in all categories report personnel placement as the least computerized application in the general administrative service area.

The percentage of applications reported on-line in the general administrative service area is below the average in all institutional categories except the very smallest institutions, where the percentage reported on-line is well above the average.

Auxiliary service applications are reported at a higher frequency by private than by public institutions, however, within this application area all categories of institutions report the student and faculty/staff directory systems most often. Food service menu and inventory and faculty club billing are the least reported applications in this area.

The percentage of auxiliary service applications reported online is generally below the average except in the smaller institution categories, where it is well above average in the smallest and slightly above average in the 500 to 2,499 student category.

Logistics and related service applications as a group are reported more often by public than by private institutions, and the number of applications reported increases both with institutional degree level and with institution size. Within the application area, all institutional categories report equipment inventory and vendor information systems the most and crime reporting the least.

The middle categories of institutional degree level and size report a lower than average percentage of the logistics and related service applications operating in an on-line mode while the doctorate and associate degree level and the smallest and largest institution size categories report above average percentages of on-line operations.

Physical plant operations is the major application area reported least by all institutions, and the frequency of reporting increases only slightly by degree level and by institution size. The rank order of reporting within the application area is almost identical for all categories of institutions, with physical plant accounting first and job scheduling or key inventory last.

In all categories, the percentage of physical plant applications reported operating in an on-line mode is lower than the average for all other applications.

Admissions and records applications are reported most often by all categories of institutions, and the number of applications reported in this area increases both by degree level and by institution size. The applications within this area are reported in essentially the same order of frequency by institutions in all degree level and institution size categories. Class rosters and term student records are the most often reported and correspondence course records is the least often reported. Degree requirements evaluation is also reported infrequently, probably because of the difficulty in defining the problem.

Admissions and records applications are reported operating in an on-line mode slightly above the average in all institutional categories.

Financial aid administration applications are reported at a higher level by private institutions than by public institutions, even though the reverse is true for financial aid accounting. The number of financial aid administration applications reported increases both by institutional degree level and by institution size. Within the application area, public and private institutions report the applications in the same rank order, however the doctorate level institutions report financial awards the most often while all other degree levels report that application third. Institutions at all degree levels report financial aid evaluation the least.

The smallest institutions report financial aid evaluation the most often and the largest report it second, while institutions in the other three size categories report that application the least.

This indicates that the very small and the very large institutions have placed more emphasis on computerizing financial aid evaluation and awards while the other institutions have placed more emphasis on work-study and student employment records.

The smallest institutions report almost half the financial aid administration applications operating in an on-line mode, but all the other categories report on-line operations in this area at an average level.

Library applications are reported by a relatively small number of institutions; however, the number of applications reported does increase by institutional degree level and by institution size. Cataloging is the application reported frequently by institutions in all categories, however serials holdings is reported most often by institutions at the doctorate level and by larger institutions. Fugitive material indexing is the least reported application by institutions in all categories.

The library computer applications generally are reported to be operating in an on-line mode (40% by all institutions). However, private institutions report almost 60% on-line operations. Also, the smaller institutions reported a high percentage (70%) of their library computer systems operating on-line; only seven reported any computer applications in the library.

Other administrative applications, primarily alumni and foundation records, are ranked fourth in reporting by private institutions and sixth by public institutions. The number of applications reported increases both by degree level and by size, and the number of reported on-line applications is slightly below the average for all institutional categories. Within the area, alumni records is the most often reported application and teacher placement and fraternity/sorority rush records are the least often reported. Foundation and gift records, teacher evaluation, and test scoring and analysis are also reported often by most institutions.

Hospital applications are reported by only a few institutions, so little analysis was done in this area. Both public and private institutions report the applications in approximately the same rank order, with patient billing/accounts receivable, financial information systems, and patient registration/admission the most often reported applications and housekeeping systems the least often reported. It is interesting to note that public institutions report a much higher percentage of their hospital applications operating on-line than do private institutions, while the reverse is true in almost all other application areas.

Trends in Administrative Information Systems

The use of computers for administrative data processing is increasing rapidly in colleges and universities. The 1976-77 Fourth Inventory of Computing in Higher Education (FICHE) data indicates that 45% of the reported usage of computers was for administrative purposes. As the price of computer hardware decreases, more and more institutions will be able to afford to automate administrative tasks. Unfortunately, the cost of qualified personnel to develop the needed integrated administrative information systems is increasing, and the supply of these people is limited. With decreasing enrollments and the attendant tight budgets, it is unlikely that all colleges and universities can offer competitive salaries for good software development people; therefore, alternatives must be considered.

One alternative available to institutions computerizing administrative information systems is the use of proprietary software. While proprietary packages are general, and usually require some adjustment on the part of the institution, this alternative must be compared to the cost and time associated with internal development of administrative systems. Another alternative route to computer-based administrative systems is through cooperative development. Several groups of institutions are currently engaged in cooperative development projects; however, none have been completed, so it is too early to evaluate this alternative.

The availability of computer technology, both hardware and software, at lower prices will require that top administrators of colleges and universities learn more about the management of computer-based information systems at the executive level. The alternatives, the costs, and the decisions required to choose an appropriate strategy for each institution must be considered at the institutional policy level rather than relegated to the technical level.

Distributed Processing

One current trend toward distributed processing in computing involves moving computer processing capabilities into the user's office. Whether this is done through the use of on-line terminals connected to a central computer, or by interconnected minicomputers, there is a definite trend in colleges and universities to move the input preparation and inquiry capability to the functional offices of the institution. The fact that the smaller institutions and the very large institutions report a high percentage of their systems operating in an on-line mode is a clear indication that colleges and universities are following this general trend.

Organization of Administrative Information Systems

The role of the administrative information systems director in colleges and universities is changing from computer installation manager to "procurer" of the appropriate computer capability and "distributor" of that capability to the appropriate users throughout the institution. The computer capability may involve a large central installation, a network of minicomputers, remote job entry stations to another institution, or any combination of these alternatives. In addition to the wide range of hardware alternatives, there are also many alternatives available in the area of support software and application software, requiring that the manager of the information systems resource take a broader view of the possibilities than the traditional data processing director.

In the past, the acquisition of a computer was considered a one-time project every five to ten years. The current rapid rate of change in both capabilities and cost of technology require that the manager of the information systems resource constantly evaluate new hardware and software in light of current capabilities and planned needs.

The organizational placement of administrative information systems in colleges and universities is usually unique to the political structure of each institution. However, there is a trend for the head of the administrative information systems unit to report to the executive level of institutional management. Many studies have shown that the reporting level of the administrative systems department correlates highly with the success of that department. A major reason for the administrative information systems department to report at a high level is to insure that individual operational information systems are designed and implemented in a way that will allow integration of the operational information into management support systems. The computer facility that supports the administrative information systems may be combined with the academic unit, a separate administrative unit, or even be remote from the campus. Many times the computer facility is treated as a utility, operated by one unit for use by many. There is a clear trend, though, for the control of the design of administrative information systems to be centralized, even in cases where the operation of those systems is decentralized.

An administrative systems advisory committee composed of the major users and representatives of each level of academic administration is used by many institutions to achieve coordination of the activities of the administrative information systems department. These committees typically review and recommend approval of all information systems development plans for the institution. The committees are advisory to top institutional management, and are appointed to review plans rather than deal with the day-to-day management problems of the computer center or administrative systems office.

Conclusion

The summaries of the 1976-77 FICHE data indicate a wide range of use of computer-based administrative information systems. As institutions with computers add more applications, and as more institutions acquire computers, the effective use of the technology will require institutional administrators to stay abreast of the many alternative strategies available in order to choose the appropriate solutions for each institution. These decisions will have to be made in a rapidly changing technical and economic environment where major announcements appear weekly. The institutional information systems operating in this environment will have to be both stable and adaptable to changing conditions . . . no small order for even the best administrators.

Charts

These charts show the rank order of administrative computer applications as reported by public and private institutions. The first chart shows the order for the eleven major administrative areas in order by the frequency reported for each area using the total number of institutions reporting batch and on-line computer applications. Similar charts are shown for applications within each of eleven major administrative areas. The lines connecting the same application within each chart indicate the difference in rank order between the public and private institutions. Horizontal lines indicate the same rank order, while the steepness of the connecting lines indicates the level of difference in rank order of the application between public and private institutions. This presentation provides an immediate visual picture of the differences in the rank order of the applications.

Chart 4.1: Rank Order of the Eleven Major Administrative Areas

Rank	Public Institutions	Private Institutions
1	Admissions and Records	Admissions and Records
2	Financial Management	Financial Management
3	Planning, Mgmt & Inst Research	Planning, Mgmt & Inst Research
4	General Admin Service	Other Administrative
5	Logistical & Related Services	Auxiliary Service
6	Other Administrative	Financial Aid
7	Auxiliary Service	General Admin Service
8	Library	Library
9	Financial Aid	Logistical & Related Services
10	Physical Plant Operations	Physical Plant Operations
11	Hospital	Hospital

Chart 4.2: Planning, Management & Institutional Research Applications

Rank	Public Institutions	Private Institutions
1	Hegis Reporting	Budget Preparation
2	Faculty Salary Analysis	Budget Analysis
3	Institutional Cost Studies	Budget Position Control
4	Budget Analysis	Hegis Reporting
5	Budget Position Control	Faculty Salary Analysis
6	Budget Preparation	Institutional Cost Studies
7	Support Staff Salary Analysis	Support Staff Salary Analysis
8	Faculty Activity Analysis	Budget Forecasting
9	Institutional Coding Structure	Faculty Activity Analysis
10	Data Element Dictionary	Institutional Coding Structure
11	Enrollment Forecasting	Enrollment Forecasting
12	Budget Forecasting	Student Flow Modeling
13	Student Flow Modeling	Long Range Planning
14	Resource Requirements Modeling	Data Element Dictionary
15	Support Staff Activity Anlysis	Resource Requirements Modeling
16	Long Range Planning	Support Staff Activity Analysis

These charts show the rank order of administrative computer applications as reported by public and private institutions. The first chart shows the order for the eleven major administrative areas in order by the frequency reported for each area using the total number of institutions reporting batch and on-line computer applications. Similar charts are shown for applications within each of eleven major administrative areas. The lines connecting the same application within each chart indicate the difference in rank order between the public and private institutions. Horizontal lines indicate the same rank order, while the steepness of the connecting lines indicates the level of difference in rank order of the application between public and private institutions. This presentation provides an immediate visual picture of the differences in the rank order of the applications.

Chart 4.3: Financial Management Applications

Rank	Public Institutions	Private Institutions
1	Payroll	Payroll
2	Departmental Expenditures	Departmental Expenditures
3	General Fund Expenditures	General Fund Expenditures
4	Tuition & Fee Accounting	Student Accounts Receivable
5	General Fund Ledger	Tuition & Fee Accounting
6	Employee Benefit Accounting	General Fund Ledger
7	Retirement System Accounting	General Accounts Receivable
8	Financial Aid Accounting	Residence Hall Accounting
9	Accounts Payable	Employee Benefit Accounting
10	Student Accounts Receivable	Retirement System Accounting
11	General Accounts Receivable	Accounts Payable
12	Bank Account Reconciliation	Financial Aid Accounting
13	Stores Accounting	Bank Account Reconciliation
14	Telephone Accounting	Telephone Accounting
15	Residence Hall Accounting	Research Project Accounting
16	Grant and Contract Admin	Stores Accounting
17	Research Project Accounting	Grant and Contract Admin
18	Cash Flow Projection	Investment Records
19	Investment Records	Cash Flow Projection
20	Research Proposal Monitoring	Investment Evaluation
21	Investment Evaluation	Research Proposal Monitoring

Chart 4.4: General Administrative Service Applications

Rank	Public Institutions	Private Institutions
1	Facilities Inventory (Space)	Personnel Records
2	Classroom Utilization Analysis	Facilities Inventory (Space)
3	Personnel Records	Classroom Utilization Analysis
4	Facilities Utilization Analysis	HEW Compliance Reporting
5	HEW Compliance Reporting	Staff Ethnic Group Reporting
6	Staff Ethnic Group Reporting	Facilities Utilization Analysis
7	Civil Service Position Records	Personnel Evaluation
8	Personnel Evaluation	Personnel Placement
9	Personnel Placement	Civil Service Position Records

Chart 4.5: Auxiliary Service Applications

Rank	Public Institutions	Private Institutions
1	Student Directory Preparation	Student Directory Preparation
2	Faculty/Staff Directory	Faculty Staff Directory
3	Student Housing Reports	Student Housing Reports
4	Bookstore Inventory & Operations	Residence Hall Assignment
5	Residence Hall Assignment	Bookstore Inventory & Operations
6	Food Service Menu & Inventory	Faculty Club Billing
7	Faculty Club Billing	Food Service Menu & Inventory

Chart 4.6: Logistics and Related Services Applications

Rank	Public Institutions	Private Institutions
1	Equipment Inventory	Vendor Information System
2	Vendor Information System	Equipment Inventory
3	Stores Inventory	Purchasing Information System
4	Purchasing Information System	Automobile Registration
5	Automobile Registration	Purchase Order Follow-up
6	Purchase Order Follow-up	Stores Inventory
7	Traffic Violation Records	Traffic Violation Records
8	Car Pool Matching	Car Pool Matching
9	Motor Pool Records	Parking Lot Space Assignment
10	Parking Lot Space Assignment	Office Machine Repair Control
11	Office Machine Repair Control	Motor Pool Records
12	Crime Reporting	Crime Reporting

Chart 4.7: Physical Plant Operations

Rank	Public Institutions	Private Institutions
1	Physical Plant Accounting	Physical Plant Accounting
2	Building Maintenance Costs	Building Maintenance Costs
3	Key Inventory	Key Inventory
4	Equipment Preventative Maint.	Equipment Preventative Maint.
5	Physical Plant Job Scheduling	Physical Plant Job Scheduling

Chart 4.8: Admissions and Records Applications

Rank	Public Institutions	Private Institutions
1	Class Rosters	Class Rosters
2	Term Grade Reporting	Term Grade Reporting
3	Term Student Records & Reports	Term Student Records & Reports
4	Enrollment Statistics	Student Registration Processing
5	Enrollment Reporting	Enrollment Statistics
6	Course Add/Drop Processing	Enrollment Reporting
7	Student Registration Processing	Course Add/Drop Processing
8	Student Ethnic Group Reporting	Undergrad Admissions Processing
9	Undergrad Admissions Processing	Tuition & Fee Assessment
10	Schedule of Classes Preparation	Student Ethnic Group Reporting
11	Course Catalog Records	Student Transcript Records
12	Honors Program Records	Schedule of Classes Preparation
13	Student Transcript Records	Course Catalog Records
14	Tuition & Fee Assessment	High School Testing Records
15	Student Class Scheduling	Student Class Scheduling
16	High School Testing Records	Honors Program Records
17	Graduate Admissions Processing	Graduate Admissions Processing
18	Degree Requirements Evaluation	Degree Requirements Evaluation
19	Correspondence Course Records	Correspondence Course Records

Chart 4.9: Financial Aid Administration Applications

Rank	Public Institutions	Private Institutions
1	Work Study Records	Work Study Records
2	Student Employment Records	Student Employment Records
3	Financial Aid Awards	Financial Aid Awards
4	Financial Aid Evaluation	Financial Aid Evaluation

Chart 4.10: Library Applications

Rank	Public Institutions	Private Institutions
1	Serials Holdings	Cataloging
2	Cataloging	Card & Material Prep. & Control
3	Acquisitions	Circulation Control
4	Bibliographical Search Service	Bibliographical Search Service
5	Card & Material Prep. & Control	Serials Holdings
6	Circulation Control	Acquisitions
7	Educational Media Services	Educational Media Services
8	Fugitive Material Indexing	Fugitive Material Indexing

Chart 4.11: Other Administrative Applications

Rank	Public Institutions	Private Institutions
1	Alumni Records	Alumni Records
2	Test Scoring & Analysis	Foundation & Gift Records
3	Teacher Evaluation	Teacher Evaluation
4	Foundation & Gift Records	Test Scoring & Analysis
5	Athletic Event Ticket System	Student Psychological Testing
6	Student Counseling Records	Student Counseling Records
7	Student Psychological Testing	Athletic Event Ticket System
8	Curriculum Planning	Curriculum Planning
9	Fraternity/Sorority Rush Records	Fraternity/Sorority Rush Records
10	Teacher Placement	Teacher Placement

Chart 4.12: Hospital Applications

Rank	Public Institutions	Private Institutions
1	Patient Billing/Accts. Receivable	Patient Billing/Accts. Receivable
2	Patient Registration/Admission	Hospital Financial Info. System
3	Hospital Financial Info. System	Patient Registration/Admission
4	Hospital Census	Hospital Census
5	Medical Records	Medical Records
6	Laboratory Information System	Laboratory Information System
7	Central Supply Inventory	Central Supply Inventory
8	Pharmacy Information System	Pharmacy Information System
9	Radiology Information System	Appointments & Scheduling
10	Appointments & Scheduling	Radiology Information System
11	Communications & Order Entry	Dietary/Food Service
12	Nursing Station Support System	Nursing Station Support System
13	Dietary/Food Service	Physician Support System
14	Physician Support System	Communications & Order Entry
15	Housekeeping	Housekeeping

The following four charts show the three most frequently and the one least frequently reported administrative computer applications for each of the eleven administrative areas by degree level and by institution size. The most reported three applications are indicated by number, and the least reported application is indicated by (L). When applications are ranked the same by adjacent categories, the applications are listed together.

Chart 4.13: Applications by Degree Level (Part 1)

Planning, Management, & Institutional Research Applications

Doctorate

(1) Faculty Salary Analysis
(2) Budget Preparation
(3) Support Staff Salary Analysis
(L) Long Range Planning

Masters

(1) Hegis Reporting
(2) Budget Analysis
(3) Budget Position Control
(L) Long Range Planning

Bachelors

(1) Hegis Reporting
(2) Budget Position Control
(3) Budget Analysis
(L) Support Staff Salary Analysis

Associate

(1) Hegis Reporting
(2) Institutional Cost Studies
(3) Budget Analysis
(L) Long Range Planning

Financial Management Applications

Doctorate

(1) Payroll
(2) Departmental Expenditures
(3) General Fund Expenditures
(L) Investment Evaluation

Masters, Bachelors & Associate

(1) Payroll
(2) Departmental Expenditures
(3) General Fund Expenditures
(L) Research Proposal Monitoring

General Administrative Service Applications

Doctorate

(1) Personnel Records
(2) Facilities Inventory (Space)
(3) Staff Ethnic Group Reporting
(L) Personnel Placement

Masters

(1) Personnel Records
(2) Facilities Inventory (Space)
(3) Classroom Utilization Analysis
(L) Personnel Placement

Bachelors

(1) Facilities Inventory (Space)
(2) Personnel Records
(3) Classroom Utilization Analysis
(L) Personnel Placement

Associate

(1) Classroom Utilization Analysis
(2) Facilities Inventory (Space)
(3) Facilities Utilization Analysis
(L) Personnel Placement

Auxiliary Service Applications

Doctorate

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Student Housing Reports
(L) Food Service Menu & Inventory

Masters

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Student Housing Reports
(L) Faculty Club Billing

Bachelors

(1) Student Directory Preparation
(2) Student Housing Reports
(3) Faculty/Staff Directory
(L) Food Service Menu & Inventory

Associate

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Bookstore Inventory & Operations
(L) Faculty Club Billing

Chart 4.14: Applications by Degree Level (Part 2)

Logistics and Related Services Applications

Doctorate
(1) Equipment Inventory
(2) Vendor Information System
(3) Stores Inventory
(L) Crime Reporting

Bachelors
(1) Equipment Inventory
(2) Vendor Information System
(3) Automobile Registration
(L) Crime Reporting

Masters
(1) Equipment Inventory
(2) Vendor Information System
(3) Automobile Registration
(L) Crime Reporting

Associate
(1) Equipment Inventory
(2) Vendor Information System
(3) Purchasing Information System
(L) Crime Reporting

Physical Plant Operations

Doctorate
(1) Physical Plant Accounting
(2) Building Maintenance Costs
(3) Physical Plant Job Scheduling
(L) Key Inventory

Masters, Bachelors & Associate
(1) Physical Plant Accounting
(2) Building Maintenance Costs
(3) Key Inventory
(L) Physical Plant Job Scheduling

Admissions & Records Applications

All Four Degree Levels the Same
(1) Class Rosters
(2) Term Grade Reporting
(3) Term Student Records & Reports
(L) Correspondence Course Records

Financial Aid Administration

Doctorate
(1) Financial Awards
(2) Work Study Records
(3) Student Employment Records
(L) Financial Aid Evaluation

Masters, Bachelors & Associate
(1) Work Study Records
(2) Student Employment Records
(3) Financial Awards
(L) Financial Aid Evaluation

Library Applications

Doctorate
(1) Serials Holdings
(2) Cataloging
(3) Bibliographical Search Service
(L) Fugitive Material Indexing

Bachelors
(1) Cataloging
(2) Card & Material Prep. & Control
(3) Bibliographical Search Service
(L) Fugitive Material Indexing

Masters
(1) Cataloging
(2) Serials Holdings
(3) Card & Material Prep. & Control
(L) Fugitive Material Indexing

Associate
(1) Acquisitions
(2) Cataloging
(3) Educational Media Services
(L) Fugitive Material Indexing

Other Administrative Applications

Doctorate
(1) Alumni Records
(2) Foundation & Gift Records
(3) Test Scoring & Analysis
(L) Teacher Placement

Bachelors
(1) Alumni Records
(2) Foundation & Gift Records
(3) Teacher Evaluation
(L) Teacher Placement

Masters
(1) Alumni Records
(2) Teacher Evaluation
(3) Test Scoring & Analysis
(L) Fraternity/Sorority Rush Records

Associate
(1) Test Scoring & Analysis
(2) Alumni Records
(3) Teacher Evaluation
(L) Fraternity/Sorority Rush Records

Hospital Applications not ranked by level due to small numbers reported.

Chart 4.15: Applications by Institution Size (Part 1)

Planning, Management & Institutional Research Applications

Less Than 500

(1) Budget Position Control
(2) Budget Analysis
(3) Institutional Cost Studies
(L) Resource Requirements Modeling

500 to 2,499

(1) Budget Position Control
(2) Budget Analysis & Hegis Reporting
(3) Budget Preparation
(L) Support Staff Activity Analysis

2,500 to 9,999 & 10,000 to 19,999

(1) Hegis Reporting
(2) Faculty Salary Analysis
(3) Support Staff Salary Analysis
(L) Long Range Planning

20,000 and Over

(1) Faculty Salary Analysis
(2) Budget Preparation
(3) Institutional Cost Studies
(L) Long Range Planning

Financial Management Applications

Less Than 500

(1) Payroll
(2) General Fund Expenditures
(3) Departmental Expenditures
(L) Research Proposal Monitoring

500 to 2,499 & 2,500 to 9,999

(1) Payroll
(2) Departmental Expenditures
(3) General Fund Expenditures
(L) Research Proposal Monitoring

10,000 to 19,999

(1) Payroll
(2) Departmental Expenditures
(3) General Fund Expenditures
(L) Research Proposal Monitoring

20,000 and Over

(1) General Fund Expenditures
(2) Payroll & Departmental Expenditures
(3) Fin Aid & Tuition & Fee Accounting
(L) Investment Evaluation

General Administrative Services Applications

Less Than 500

(1) Personnel Records
(2) Facilities Inventory (Space)
(3) Classroom Utilization Analysis
(L) Personnel Placement

500 to 2,499

(1) Facilities Inventory (Space)
(2) Classroom Utilization Analysis
(3) Personnel Records
(L) Personnel Placement

2,500 to 9,999 & 10,000 to 19,999

(1) Personnel Records
(2) Facilities Inventory (Space)
(3) Classroom Utilization Analysis
(L) Personnel Placement

20,000 and Over

(1) Facilities Inventory (Space)
(2) Classroom Utilization Analysis
(3) Staff Ethnic Group Reporting
(L) Personnel Placement

Auxiliary Service Applications

Less Than 500

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Bookstore Inventory & Operations
(L) Food Service Menu & Inventory

500 to 2,499 & 2,500 to 9,999

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Student Housing Reports
(L) Food Service Menu & Inventory

10,000 to 19,999

(1) Faculty/Staff Directory
(2) Student Directory Preparation
(3) Student Housing Reports
(L) Faculty Club Billing

20,000 and Over

(1) Student Directory Preparation
(2) Faculty/Staff Directory
(3) Student Housing Reports
(L) Faculty Club Billing

Logistics & Related Services

Less Than 500 & 500 to 2,499

(1) Equipment Inventory
(2) Vendor Information System
(3) Purchase Order Follow-up
(L) Crime Reporting

2,500 to 9,999

(1) Equipment Inventory
(2) Vendor Information System
(3) Purchasing Information System
(L) Crime Reporting

10,000 to 19,999

(1) Equipment Inventory
(2) Vendor Information System
(3) Automobile Registration
(L) Crime Reporting

20,000 and Over

(1) Equipment Inventory
(2) Stores Inventory
(3) Vendor Information System
(L) Office Machine Repair Control

Chart 4.16: Applications by Institution Size (Part 2)

Physical Plant Operations

Less Than 500 to 19,999 (1st 4 Grps)

(1) Physical Plant Accounting
(2) Building Maintenance Costs
(3) Key Inventory
(L) Physical Plant Job Scheduling

20,000 and Over

(1) Physical Plant Accounting
(2) Building Maintenance Costs
(3) Physical Plant Job Scheduling
(L) Key Inventory

Admissions & Records Applications

Less Than 500

(1) Term Grade Reporting
(2) Term Student Records & Reports
(3) Class Rosters
(L) Correspondence Course Records

500 to 2,499

(1) Class Rosters
(2) Term Grade Reporting
(3) Term Student Records & Reports
(L) Correspondence Course Records

2,500 to 9,999

(1) Class Rosters
(2) Term Grade Reporting
(3) Student Registration & Others
(L) Correspondence Course Records

10,000 to 19,999 & 20,000 and Over

(1) Enrollment Statistics & Others
(2) Class Rosters & Others
(3) Student Registration & Others
(L) Correspondence Course Records

Financial Aid Administration

Less Than 500

(1) Financial Aid Evaluation
(2) Student Employment Records
(3) Financial Awards
(L) Work Study Records

500 to 2,499 & 2,500 to 9,999

(1) Work Study Records
(2) Student Employment Records
(3) Financial Awards
(L) Financial Aid Evaluation

10,000 to 19,999

(1) Work Study Records
(2) Financial Awards
(3) Student Employment Records
(L) Financial Aid Evaluation

20,000 and Over

(1) Financial Awards
(2) Financial Aid Evaluation
(3) Work Study Records
(L) Student Employment Records

Library Applications

500 to 2,499

(1) Cataloging
(2) Card & Material Prep. & Control
(3) Serials Holdings
(L) Fugitive Materials Indexing

2,500 to 9,999

(1) Cataloging
(2) Serials Holdings
(3) Acquisitions
(L) Fugitive Materials Indexing

10,000 to 19,999

(1) Serials Holdings
(2) Acquisitions
(3) Card & Material Prep. & Control
(L) Fugitive Material Indexing

20,000 and Over

(1) Serials Holdings & Circulation
(2) Cataloging
(3) Bibliographical Search Service
(L) Fugitive Material Indexing

Other Administrative Applications

Less Than 500

(1) Alumni Records
(2) Test Scoring & Analysis
(3) Foundation & Gift Records
(L) Several Applications

500 to 2,499

(1) Alumni Records
(2) Foundation & Gift Records
(3) Teacher Evaluation
(L) Fraternity/Sorority Rush Records

2,500 to 9,999 & 10,000 to 19,999

(1) Alumni Records
(2) Test Scoring & Analysis
(3) Teacher Evaluation
(L) Fraternity/Sorority Rush Records

20,000 and Over

(1) Test Scoring & Analysis
(2) Alumni Records
(3) Teacher Evaluation
(L) Fraternity/Sorority Rush Records

Hospital Applications not ranked by size due to small numbers reported.

Notes

1. John W. Hamblen, *Inventory of Computers in U.S. Higher Education 1966-67: Utilization and Related Degree Programs* (Washington, D.C.: U.S. Government Printing Office), Library of Congress 74-609402.

2. Richard L. Mann, Charles R. Thomas, Richard C. Williams, and Robert A. Wallhaus, *An Overview of Two Recent Surveys of Administrative Computer Operations in Higher Education* (Boulder, Colo.: NCHEMS at WICHE, 1975).

3. Warren W. Gulko, *Program Classification Structure*, First Edition (Boulder, Colo.: NCHEMS at WICHE, January, 1972).

5

Instructional Uses of Computers in Higher Education

Karl L. Zinn

This chapter departs from the inventory data somewhat in order to accommodate interpretation of a rapidly changing technology. The inventory conducted in 1976-77 reflects instructional use of computers through time-shared facilities and some department-based systems as seen by staff at computing centers at colleges and universities. An informal telephone survey made in April and May of 1979 indicates that already at some institutions the amount of instructional computing delivered by standalone, single-user systems exceeds that provided to students by centralized computers. Indeed, growth is so rapid that in order to have any chance of indicating the current state of instructional uses of computing in higher education at the time of publication of this book, we must deal in projections. The reader seeking firm data has to be content with the results of the 1977 inventory. The interpretations in this chapter are based on trends evident in the inventory plus informal data acquired through the more recent survey and through personal communications, including telephone conversations, correspondence, and site visits.

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This chapter provides a brief history of instructional uses of computers in higher education, particularly in engineering and the sciences, and a short summary of typical uses. Primary attention throughout the remainder of the chapter is given to interpretation of near-term uses and some discussion of implications for the future.

History

Instructional uses of computers were demonstrated at a number of universities throughout the United States in the 1950s. Thoughtful engineers and scientists, anticipating the impact of computing in their fields, developed exercises through which students were introduced to computers as tools.

Notable among these early efforts was a study directed by Donald Katz at the University of Michigan and funded by the Ford Foundation. A team of engineering educators from throughout the country contributed problem sets and supporting materials which significantly influenced computing and education in engineering during the next decade. Dissemination of those ideas and materials was carried on by workshops and institutes as well as distribution of printed packages.

In the late 1950s many colleges and universities introduced regular instruction in computer programming and applications. Computing in the sciences received quite a boost from time-sharing systems developed in the early 1960s; applications became much easier in subjects other than computer programming and engineering. Indeed, the first multiple-user system was one designed in 1959 for computer-based instruction in statistics, German, and stenotype using an IBM 650. A short history of computer-assisted instruction during this time period is given in a survey published in 1970.[1]

By the mid-'60s attention to instructional computing had been picked up by various professional associations. The Commission on College Physics held a series of meetings, workshops, and institutes which had considerable impact on the use of computing in physics teaching. The American Chemical Society established a committee for exchange of programs and also encouraged conferences and workshops. The Institute of Electronic and Electrical Engineers initiated an annual conference on computers in engineering education. The American Political Science Association, along with the Interuniversity Consortium for Political and Social Research, prepared data bases and procedures by which students in political and social sciences could readily interact with computer data analysis routines without detailed knowledge of the technology. These materials and ideas have been distributed widely through the summer institute program of the consortium and workshops at professional meetings. In the field of geography a study series was developed and a program exchange library established to assist college teachers in that discipline. Computer uses in medical education have been advanced by many different organizations and institutions. The focal point since the late '60s has been the Lister Hill National Center for Biomedical Communications, part of the National Library of Medicine. An annual conference on on-line use of computers in psychology was begun in 1964. Although it was concerned initially with research use of computers, increasing attention has been given to instructional activities with computers.

Regional services provided another boost for instructional computing. With support from the National Science Foundation, about twenty university computing facilities made remote access possible for nearby colleges otherwise lacking in appropriate instructional computing. Some of these arrangements only demonstrated that something important could be done with computers. Institutions had to get their own facilities before they could provide the range of services needed to support instructional applications. Other regional services were quite successful over a long period of time, even continuing today. Insight into the contributors to success can be found in reports from that period.

A number of professional organizations made contributions through special interest groups, workshops, conferences, and the like. First among them was the Association for Computing Machinery with the establishment of special interest groups on university computer centers, computer science education, and later, one specifically for computer uses in education. The umbrella organization for engineering and computer professional societies, American Federation of Information Processing Societies (AFIPS), contributed additional educational services. Later the International Federation for Information Processing, of which AFIPS is a member, provided an international forum through working groups and world conferences on computer education in 1970 and 1975.

The Association for Educational Data Systems was initially oriented to data services in precollege institutions. However, it promoted ideas for clubs, programming contests, and other educational activities which were quite influential. Today it covers the full range of computer uses in education and for all levels of institutions.

The Association for Development of Computer-based Instructional Systems grew out of a users group for a dedicated instructional system (the IBM 1500). The organization has not been large but includes people from most of the major computer-assisted instruction projects, and now has special interest groups on medical education, the PLATO Computer-based Education System, and other facilities and topical areas.

A somewhat different kind of organization stands out among all of these for a quite notable contribution. EDUCOM, the Interuniversity Communications Council, has been contributing to computers in higher education since the mid-'60s. A major planning conference in 1965 helped set directions for the field. A summer study in 1966 influenced networking activities. Task force activity during the second half of the decade shaped new projects. A network study in the early '70s led to a pilot network and later to EDUNET, which now contributes in major ways to sharing of software and other computing resources among colleges and universities.

Instructional uses did not benefit from all the network developments and regional services as much as planners had hoped. Instruction does not have sufficient priority in college and university budgets for computer use, and learning activities lack the urgency of other kinds of network activities. Furthermore, changes in techniques of college teaching and learning come about through exploration by faculty and students, one by one, and school by school. Perhaps personal computers, another innovation now more personal than large computers and national networks, will multiply tenfold what has already been accomplished.

Domain of Instructional Uses

Learning about the Computer

Learning about the computer is the most rapidly growing area of instructional computing. Computing instruction follows quite naturally from the introduction of computers into many parts of society and into homes directly. As experience with computers becomes commonplace for college students, professors can use the computer and its procedures as metaphors for other processes and constructs. Education about computers provides tools useful in other learning. The following paragraphs comment on computer literacy, professional development, inservice training of educators, and personal computing.

Computer literacy for all students, the ability to program a computer and/or make good use of preprogrammed applications, is established now in some colleges. Computer programming may be required (or assumed and offered only as a noncredit course) so computing skills can be put to use in courses in mathematics, sciences, engineering, and some other professions. The extent of computer literacy throughout the college population is still surprisingly low, but inexpensive computing devices and the popularity of the activity with students will increase the percentage dramatically in the next few years.

Professional development regarding computer use is common for many areas already; accountants, bankers, engineers, and others whose professional activities depend on automatic computation and information processing are refreshing their computer skills and obtaining new ones. Additional professions are finding computer assistance indispensible, and information is offered through special courses and institutes for architecture, law, medicine, and others.

Colleges and universities have a key role to play in the inservice training of teachers, which is essential if public education is to catch up with the rapid change of technology. University institutes offer skills training during the school year and in the summer. Sound information and constructive attitudes regarding computers in education are essential to the success of new programs in public schools and community colleges.

Personal computing in homes shows the greatest prospect for impact on learning about the computer. By the end of 1978, personal computers were in use in about 350,000 homes and offices. Many of the purchasers use these devices only with packaged application programs, as are the preprogrammed video games; but all the equipment is programmable and includes local storage for saving user-designed programs.

Learning through the Computer

In the past, the core of educational computing activity was drill, practice, diagnostic testing, and question-and-answer tutorials. Today these continue to be the major modes of learning in operational systems (e.g., the PLATO System of the University of Illinois and Control Data Corporation, Computer Curriculum Corporation systems, IBM, Hewlett-Packard, and Digital Equipment time-sharing systems, and the Univac system). Even though these modes will be overshadowed for a time by a dramatic growth of learning about and learning with the computer, they will remain viable instances of computer applications, readily accepted because of their familiarity, moderate cost, and convenience of total systems. Personal computers will take over delivery of instruction only after they incorporate the necessary storage facility for curriculum materials and performance data, and only to the extent their owners wish to use them in that mode.

Learning with the Computer

The computer as an aid to learning, and as an adjunct tool for the learner, is taking on new dimensions now that computing is inexpensive and portable. Hand calculators used in the laboratory, classroom, and study hall have taken on the characteristics of computers: stored programs, program libraries, peripheral storage, printers, graphics, etc. As these least expensive computing devices incorporate general characteristics, the general-purpose computers are decreasing in price to match the most capable calculators. Practical uses include simulation, gaming, problem solving, and creative activities.

Simulation and gaming have always been popular with teachers and students. Now these entertaining activities are appearing in academically respectable textbooks and laboratory materials. Problem-solving activities once required knowledge of programming, unless cleverly imbedded in a tutorial sequence which prompted for the parameters and equations or whatever was needed. Now problem-oriented languages, and familiarity with keypress sequences on programmable calculators, put problem solving in reach of any learner experienced in the discipline. Students can be asked to turn to a problem-solving facility on the time-sharing system or a microcomputer (or a calculator at hand) to carry out some computation or modelling activity. Creative activities in education are aided by computers very nicely, at least in experimental systems. Perhaps the most impressive overall is the first approximation to the "dynabook" developed by Allen Kay and his colleagues. Kids of all ages are able to sketch, animate, compose music, arrange words in poetic forms, and carry on many other creative activities usually reserved for specialized and advanced users of computers.

Learning Support Systems

Computer managed learning is expanding within higher education, albeit quietly and often without any note of the computer role. A significant percentage of colleges are using computer systems to aid in classroom management. Information management goes beyond instructional management to help the student as well as the instructor with information needs.

The automatic generation of learning and testing materials by computer will soon become common among a teacher's computer aids. Some tools are already quite popular, especially computer-assisted test generation. Delivery is easily handled on today's microcomputers.

Areas of Instruction

The broad range of computer uses can be shown by selecting some of the less likely uses in six areas of instruction: math, sciences, social sciences, arts and humanities, languages and communications, and the professions. The few instances given here represent only a small part of all the computer-aided learning curriculum materials.

Students in a mathematics course have used a simple computer language (LOGO) on a mini-time-sharing system or a micro to generate a mathematical system built up from primitive elements.

In a laboratory course in chemistry, preparation for use of titration equipment is aided by conceptual experience provided economically to individual students who use the graphic animation capabilities of the PLATO System (or the Commodore PET) before they go into the laboratory.

A simulated laboratory provides research experience for undergraduate students in psychology. The computer is used as a data generator. The value of the simulation depends on the activity of a classroom research community and the effectiveness of the teacher as a consultant.

In the arts and humanities computing serves as a medium of communication as well as a tool for creative work as part of learning. Perhaps the most interesting instructional use in humanities today is as an aid for scholarly work by the student. Graduate students of literature have used preprogrammed applications packages in exercises to determine authorship or analyze style. Undergraduate students explore rules of language through computer generation of poems and stories. Previously seen only on large machines, these applications are now showing up on very capable word processing systems and micros.

In language learning, aid in practice of skills is the dominant computer use. Contrary to the idea that the cost of development needs to be distributed over many students, two professors at Stanford University are programming computer assistance for a dozen specialized courses which have such low attendance that the department of Slavic languages cannot afford to staff them. With this assistance (tutoring, drills, and practice exercises) the professors plan to handle a larger number of students and in a greater variety of courses than previously possible.

Preparation for professional work accommodates as much computer use in training and education as anywhere. For example, management games are very popular in business education and natural resources; simulated cases are used in law and medicine; and design exercises depending on computer assistance are common in engineering and architecture. One of the most innovative applications is computer assistance for advanced seminars which bring together graduate students from different departments for study of a problem area (e.g., energy conservation, regional planning, or technology assessment). Each participant uses computer assistance for organizing information from diverse and sometimes unfamiliar areas, communicating in writing with others in the seminar at times other than their regular, face-to-face meetings, and drafting working papers for review by the group. The organizers of the seminar keep the group focused on the problem without minimizing important background material, and call on resource people who might not otherwise have time to participate except for the convenience offered by computer-assisted conferencing. This enables them to respond at any time of day, any day of the week, and from any user terminal or personal computer which can connect to the computer or network handling the conference.

Informal Survey of Microcomputer Use

An informal survey was conducted by telephone in April and May 1979 to collect information and ideas about the impact of microcomputers on instructional computing. The conversations were open to whatever the respondent wished to discuss. A fixed set of questions was used to provide context and to prompt comment. Respondents were not urged to provide data, since exact numbers of microcomputers are difficult to determine, and are changing continually. Any institutional count will be less than the number actually in use, since professors buying computers for personal use are bringing them into the classroom and laboratory for students to use, and some students are purchasing their own equipment for personal use in learning and research activities.

The survey covered thirty-five institutions: fifteen state universities and colleges, four community colleges, nine private universities and colleges, and seven organizations providing regional or national services. About fifty people were contacted, typically a computing center director or other administrator responsible for instructional computing and sometimes another administrator responsible for instructional resources generally. The responses are summarized under headings corresponding to the questions asked. Information and ideas picked up in the informal survey also appear elsewhere throughout this chapter.

1. *To what extent are microcomputers providing instructional computing in colleges and universities?*

Microcomputers were understood to be complete systems which operate in stand-alone mode, not microprocessors which are part of other equipment or studied directly in engineering classes, and not intelligent terminals except where they are typically used apart from the time-sharing system as well. The emphasis was on single-user, "personal" computers.

Microcomputers are already very popular in computer science, engineering, physics—areas where they are of interest as a subject of study and for instrumentation of experiments and laboratory activities. Nearly all institutions report use of microcomputers in computer and data processing education. Small machines provide opportunities to study operating systems, graphics, communications, etc., and to explore the insides of a system without risk of bringing down the central, shared system. Some courses are now specific to microcomputers: small business systems, process control, home computers, etc.

In one department of seven professors, every one has purchased a machine for use at home. In a college of engineering, two departments were putting up money ($500 each) toward the purchase of personal machines for exclusive use of individual faculty members. Two institutions estimated about fifty machines in use by students; no one reported zero.

2. *How does the number of microcomputers used by students compare with the number of terminals (stations on a time-sharing system) typically used by students for learning activities?*

Respondents from the colleges and universities, excluding the national and regional services, differed in their assessment of mix of personal computers and time-sharing for instruction: at least as many personal machines as terminals already (reported by four); as many in six months (two); in one year (five); in two years (nine); in three or more years (eight). However, the comments are more interesting and more useful than the numbers in this informal survey.

Many of the respondents offered explanations of slower campus adoption and mentioned various obstructions to acquisition of microcomputers. The best reason is satisfaction with present equipment. Graphics and rapid data rates may already be available through suitable terminals wired in directly to a central or departmental system. Stations are available in sufficient numbers, at least at some of the smaller colleges. For those with large amounts of instructional software on a time-sharing system (e.g., computer-assisted instruction), the changeover to microcomputers would be a considerable task. It is not so difficult to transfer from one microcomputer to another, if such translations have been anticipated at the time of the original design.

High schools may be ahead of colleges in acquisition of microcomputers. Funds are available for purchase; small machines handle a greater portion of what needs to be done; less resistance is encountered among teachers experienced with computers. Furthermore, research-oriented institutions need more computing power, larger storage, and a greater variety of software and applications packages.

Some of the respondents reported impressions of many more personal purchases than institutional ones. Microcomputers seem popular for word processing as well as for computation, and for self-education as well as for entertainment. Three years ago having a student who had his or her own computer was very rare. People from two universities observed that in computer science or engineering classes about 10% of students report having their own machines. In adult education computer programming classes at one of those institutions, the percent is somewhat higher (about 15%); recent purchasers tend to elect those classes.

In some places, computer professionals hold microcomputers in low regard. Only because the class enrollments are large and produce income do the computer science people tolerate the classes using BASIC and small machines in these institutions. On the other hand, in two institutions, the initiative by the computing center did not appear to have been picked up by faculty. Microcomputers were made available in public areas: students are using them, although mostly for games; faculty are staying away.

At research-oriented universities most equipment comes in through grants, and so will be oriented toward research. Three universities reported getting many machines, but not using them for instruction; individual student purchases will help this. Another way around the lack of funds for instructional equipment purchases is rental programs. Local stores in some college towns are leasing machines hoping to sell even more through that exposure, and some institutions are renting IBM 5100s on a special program which links rental to actual use. Under the program, costs for modest use average less than flat monthly rates.

Some of the computing center directors indicated they would be replacing terminals with micros which can be used as terminals. The rate of replacement depends on funding of equipment for computing facilities. Some are expecting outside grants to cover most of the replacement cost and especially the expansion. Considerable advantage can be gained from a mixture of central and local computing, but the design of systems which link processes in the shared computer and the small, personal machine is not trivial.

3. *How may instructional computing be qualitatively different for having made use of personal machines?*

Obvious changes occur in physics, chemistry, engineering and some other courses in which the general-purpose microcomputer aids in instrumentation of experiments. More dramatic differences occur in English literature or political science where a personal machine opens up new kinds of computing to students. Advantages are derived from access, speed of response, personal adaptations, and local control.

Students and faculty appear much less hesitant to use microcomputers than time-sharing terminals. So far the interest appears to transfer to the larger and more capable systems. People are getting involved who have not been computer users before. An introduction to computing is provided more easily.

Other comments about qualitative differences in use of microcomputers in college teaching and learning are discussed in the next section.

Changes in Computer Use

Personal computing is not new, but it does need reinterpretation and reassessment. For some years all students at Dartmouth College have been assumed to be computer users; the computing center ID is the same as the student ID and is valid from enrollment to graduation. At the University of California, Irvine, computing exercises are part of many courses, and it is quite common for students not enrolled in a course also to use its computing exercises just as they check out library books which were purchased for use by students in some other courses. At the University of Michigan some students have gained experience with software designed especially for handling personal note files, problem-solving procedures, and class communications.

The commercial push to sell personal computers for home use (including education) is very evident. Ads are common on television and in popular magazines. They are directed at families as well as small businesses, appealing to personal interests as well as professional. Some manufacturers approach personal computing via games and entertainment, others via programmable calculators, and some as small business systems. All these kinds of personal computers will very likely be purchased for a large number of homes and used by college-bound students. Such computers could be very helpful in educational and professional activities; machines yet to be designed will serve well these multiple purposes.

Handling Text More Efficiently

Word processing is a good example of computing that is burdensome on a time-sharing system and so is moving to an intelligent terminal. Early word processing systems could not match the central computer system in power, particularly for preparation of proposals, reports, and other lengthy documents. However, today's microcomputer-based systems can do as well in most areas and much better in some. Current equipment offers very much more than the typical central system can in ease of formatting, quality of output, and control over output. Some word processing installations on college campuses use a time-sharing system for text manipulation that might better be done on a stand-alone or satellite system. On the other hand, an inexpensive, remote terminal which can do visual mode editing (i.e., is intelligent) will open up time-sharing capabilities to many more users.

Students report a number of benefits of computer-assisted text preparation. The following comment is typical. "I have been an extensive user of the word processor for everything from a thesis and legal briefs to poetry. It is an invaluable tool. It provides a visually attractive (and impressive) finished copy. It encourages me to polish my work (it takes the pain out of going back to get it just right). Also I am more likely to work further on a project after the teacher has critiqued it. This tool makes written work more fun! At a time of declining communications skills, this may be the major advantage."

Extending Laboratory Experience

Microcomputers are used by many labs as part of the instrumentation for research purposes. Students working with such equipment in the sciences and engineering gain important educational experience. In addition, the students enjoy increasing use of microcomputers in regular labs where they are not yet needed for instrumentation: typical examples are in physical chemistry, bioengineering, biochemistry, natural resources, biology, and psychology. Virtually all of the sciences will be affected.

Another example comes from the psychology lab. Students are given a program on a microcomputer which presents stimuli and records data for simple perception and reaction time experiments. They are encouraged to revise the program to vary the experiments beyond the limits of the preprogrammed logic and parameters. The cost of the microcomputer is equivalent to that for other kinds of lab equipment. Electricity and maintenance are a little more than for an office typewriter. Economy in use is very important for lengthy studies and experimentation by undergraduates. The software of general-purpose micro provides good control of the screen display and timing.

Preparing for Labs through Simulations

Simulations have even wider spread of application. The benefits are well known: cost saving, time saving, risk reducing, etc. In addition to simulations in the science laboratories, people in political science, sociology, education, and history are putting them to use. The machine is available whenever its owner decides to use it since no telephone connection is necessary to obtain the computing power. The graphics are immediate and easily projected. These and other characteristics contribute to qualitative differences in the use of personal computers in simulation.

Motivating Learning through Games

Instructional games form a category separate from that of simulation. Well-designed instructional games have a favorable history, particularly in business, sociology, and education. Games become more interesting and potentially more valuable when they have a computer component. The computer handles complexity, control, concealment, randomness, and records. Games on microcomputers today are mostly of the arcade variety. However, faculty authors are working with publishers on marketable packages.

Expanding Tutorial Uses

Tutorial use of computers, particularly in the programmed instruction mode, has not been favored in colleges and universities. For most of the university students this approach does not give enough control over the pace and style of learning. Furthermore, the computer terminal, telephone line, processing, and storage are better used for other kinds of computer-based learning activity. However, inexpensive and personal computers may change this. When students owning personal $300 computers can buy a cassette providing something equivalent to the old "College Outline Series," then the university and its faculty will need to consider the use of microcomputers for tutorials, at least for remediation.

Building Skills in Computing

Training in computer use has been advanced in a significant way by the introduction of microcomputers. Those not concerned about computer science or computer engineering still find many places for applications in their areas: graphics in engineering, linear programming in business, information systems in law, patient records in medicine, class records in education, etc. These are only some of the places where faculty members are working on demonstration exercises or writing materials for computer education regarding micros in the professions or disciplines. In addition, there are noncredit courses designed to provide an introduction to computer use and programming which assumes access to an inexpensive, personal computer purchased or rented from a local computer store.

Implications for Planning and Research

The revolution in microelectronics requires attention to planning for new uses of computing in college teaching and learning.

1. *We should not extrapolate from (typical) computing in higher education. A revolution is going on which will put computing into everyone's home.*

Computing in higher education has been based on expensive equipment of rather limited scope. We should not make simple extrapolations from experiences with equipment and procedures which led users to consider computer efficiency more important than learner convenience. Most research on instructional computing used systems which have been made obsolete by a revolution in microelectronics. Restrictive terminals and slow data rates provided only a small window on the capabilities of computer aids to learning. New research will be done in a context which is different in qualitative and quantitative ways.

Computing equipment will be available in much larger numbers. Higher education will enjoy the use of 1,000 times more personal computers than we now have time-sharing terminals. Many of these personal devices will have a communicating option so that they can talk with other personal computers directly and with time-sharing computers.

Computing equipment will be much more responsive. The design of personal computers makes possible more rapid data rates, and this facilitates graphics and sound and other modes of communication between computer program and user.

Personal control of computing equipment will be a factor in increased use in education. Systems will be personalized for convenience, and also gain certain intangible characteristics associated with being owned and entirely under one's own control.

Computing will be common in everyday life. Not only will people know about computers and their uses, but also access to time-sharing systems and single-user machines will be common for personal use. Entertainment and schedule planning are certain to be among the applications; education and information retrieval applications are likely also if personal computers can be coupled with the large but inexpensive storage capabilities of videodiscs or their equivalents.

2. *Anticipating future capabilities and discontinuities is important. What will be the impacts of new technologies on education?*

A list of some of the implications for planners to consider is given below.

Impact on the learner. Microcomputers and video information systems will have considerable impact as tools for student learning. New intellectual skills will be needed by students who wish to use the new technologies. Some skills will become much more important because of use of the new technologies. Attitudes will change, affecting students' views of the technology employed, the topics studied, knowledge in general, sources of information, interaction with peers, etc. Not all of the changes will be beneficial.

Impact on the teacher. Quite likely, satellite and optical fibre communications will greatly improve access to current information and resource people. Changes in the role of the professor will be necessary to make use of the new technologies, but these changes will be different in various disciplines and kinds of institutions. Improved access to excellent lectures will tend to raise standards for educational materials, including live lectures as well as packaged materials. Improved access to good information will have a positive affect on the role of education in society, but not necessarily on educational institutions!

Impact on the scholar. Difficulties will arise as telecommunications replace or extend face-to-face communications. The professional meetings of scholars and teachers will change, as will the environments for scholarly work and professional training. The speed of information exchange and the pace of electronic publication will affect the quality of scholarly work, for the worse as well as for the better.

Impact on the learning community. Community centers will assume more of the delivery of education, not only through community colleges per se but in regional centers of universities. Telecommunications will, along with increased energy costs, change educational travel and campus life. In many specific ways electronic storage and transmission will replace or extend vocal communication.

The major directions of new technology in education are shaped by economic, social, and political factors. However, the benefits of such changes can be enhanced through careful attention to desirable faculty roles, improved student preparation, and more humane applications of technology. Furthermore, if planners can successfully anticipate negative side effects of technology, they will help reduce the undesirable impact, for example, on values, on social experiences, and throughout a lifetime of learning.

3. *As computing becomes more available and personalized, it becomes increasingly useful to the student as a scholar. Using the computer as a scholarly tool, the student moves more easily into a community of scholars and learners.*

Initial uses of microcomputers at universities are simply extensions of what has been successful with time-sharing systems.

Simulations become more available to students, and easier for them to modify, in history and sociology as well as in chemistry and physics. Instructional games adapted for micros become much more accessible to students in professional areas such as business and natural resources where they can be used in practice. Remediation and other tutorial activities become practical for large numbers of students and at an individual level. Commercial publishers are bringing out units for math and language skills. Applications essential to the discipline or profession are becoming more popular: graphics in aerospace engineering, linear programming in business, information systems in law, patient records in medicine, and class records in education.

Dramatically lower costs lead to rethinking what is useful to do with computers. One project is providing access to readily used word processing through micros, and examining the impact on students, assignments, grading, job seeking, and other aspects of student and professional life. Increased student research has been facilitated, and not just in computer science and computer engineering. Lab instrumentation and complex computation aids have been implemented for chemistry, biology, biochemistry, and bioengineering (medicine). Information handling and analysis is common in chemical engineering, economics, and psychology.

Many of these applications are self-justifying: professors and others making decisions about how to use resources need only see the positive changes in curriculum brought about through computer assistance. In some disciplines, equipment will be acquired as any other equipment is purchased for laboratories, or recommended for student purchase as are calculators (previously slide rules) and dictionaries. However, some of the changes will be so dramatic as to require more careful attention: deliberation by curriculum panels, reviews by technical experts, and assessment by teams of social scientists.

4. *The implications of personal computing for higher education will be dramatic!*

A shift in the responsibility for learning will come about, in part as a result of improved access to information and information processing. Authors and course designers will set general guidelines, confident that students will find considerable assistance in computer processing of text or models, as well as through improved learning skills apart from computers.

The advantage which the professor holds over the student in terms of knowledge and skills as a result of many more years of study and direct contact with others expert in the discipline will be reduced. Students will access more information directly than has been possible with book formats for typical learners. Computer aids will assist where study skills are lacking, and even sharpen those skills and promote new ones. Clearly the roles of professor and student will be altered.

The impact of computing and telecommunications on continuing and adult education will be considerable. Initially the professional person with a need for more information (and recertification) will find considerable assistance in computer-based media systems (videodisc is particularly promising). Eventually this will extend to all of adult education.

Possible Futures

New Skills of Learning, Problem Solving, and Creative Production

Computer assistance will help learners arrange multiple views of text and graphics. Skills of speed reading will be extended by aids for immediate comparisons and cross references among sections of text. Facility with graphics will extend far beyond the multi-media shows of today. Authors of textbooks and reference materials face new challenges in applying the technology and anticipating improved skills of users.

Problem-solving skills will expand in more directions than can be anticipated. Induction may be facilitated by interactive, computer-assisted deduction. Proof of the four-color map problem by students with computer assistance is only a beginning. More creative solutions to engineering problems will be especially effective.

Artistic creations will similiarly be extended beyond our present abilities to comprehend and appreciate. For a primitive example, consider today's dynamic sculpture for which a sound-light score interacts with the movements and speech of its observers. Young artists will find many new opportunities, and the world of creative art will be opened to those previously excluded by physical handicaps.

Previously untapped capacities for learning and performance will be put to use. A computer-based lab in which learners explore their own abilities may help in areas such as interhemispheric communication ("using both sides of the brain") and enhanced mechanisms of recall and pattern recognition. Unanticipated and dramatic benefits may follow from the development of synergism of the human user and various machine-aided information systems. Some of the most significant benefits may be obtained with the enhancement of communication within communities of learners, from pairing of student and tutor to an invisible college including students as well as professors.

Extending communication, processing knowledge, and building personal and interpersonal skills are important areas for future development anywhere in the world of personal computing and learning today.

Note

1. Karl L. Zinn, *An Evaluation Review of Uses of Computers in Instruction* (Project CLUE: Computer Learning Under Evaluation), Final Report U.S.O.E. Contract No. OEC-5-9-32-59-0032 (Ann Arbor: University of Michigan, 1970).

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6

Changes in Research Computing in Higher Education

Peter Lykos

Introduction

Historically serious computing began with scientific computing. As scientific computers came to be available commercially, universities began to acquire them—one computer per university—primarily to support research. Then the federal government accelerated the creation and growth of the campus computer center at universities through fourteen years of financial support delivered primarily via the National Science Foundation (NSF).

Abrupt termination of NSF funding about the time of the 1969-70 *Inventory of Computers in U.S. Higher Education*[1] sent a shock through universities, the effect of which is still being felt. About the same time, vendors began to deliver so-called supercomputers, such as the CDC 7600, and it became clear that *no* university could afford to acquire for its campus the most powerful scientific computer extant. Only the federal scientific research laboratories (and other federal agencies) or large industrial research laboratories acquired—and continue to acquire—state of the art supercomputers to support scientific

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research. In a desperate attempt to shore up the sagging finances of the campus computer center, many university administrations "froze" the acquisition of any additional computers or the flow of research dollars to off-campus facilities. Thus university computing for research entered a period of very slow growth that only recently has begun to change.

During the 1970s, change occurred in response to several factors: pressure from faculty; financing available with the write-off of the major central campus computer; gradual evolution of a "rifle shot" approach to support of research computing via line items in the budgets of federal research grants; and dramatic changes in computer technology that led to production of sophisticated and relatively inexpensive general purpose minicomputers. Many universities found themselves stuck in time, unable (or unwilling) to keep pace with evolving computer technology and subscribing to an antiquated computer support philosophy of trying to be all things to all campus users from a central campus computing facility.

There are several forces operating which affect research computing on university campuses and it is important to sort them out. The list includes the following:

- Sophistication of the faculty
- Sophistication of the administration
- Budgeting policy
- Evolution of computer hardware
- Evolution of computer software
- Evolution of Interuniversity Resource Sharing
- Evolution of federally supported national computing resources
- Sophistication of the problem-solving disciplines with the age distribution within that class skewed heavily toward the younger staff

Sophistication of the Faculty

The computer has become a major research tool spanning the entire range of university research, and spawning new research areas, all within one human generation. Approximately half of the current university faculty (and hence most of the university administration) completed its formal training before the computer appeared on the scene. Of those who received their formal training since the advent of the computer, a fraction (steadily increasing in time) has had some sort of computer-based experience as part of its graduate training. Those in the "hard" sciences are more likely to have had that experience in information storage and retrieval, laboratory automation, data reduction, or modeling of physical phenomena. Those in the "soft" sciences are more likely to have had that experience in the context of statistical treatment of data.

In universities where graduate research is being conducted, the faculty can be classified as follows:

1. Those whose research is of such a nature that computers, or computer-based services, do not play an important role at this time.
2. Those whose research is of such a nature that computers, or computer-based services, could play an important role but are not being used because of cost (increasingly less important) and/or lack of familiarity and awareness (increasingly more important).
3. Those whose research does involve use of computers but who depend almost entirely on research assistants and/or "canned" computer programs and, where appropriate, "canned" computer hardware as well.
4. Those whose research does involve use of computers and who (themselves) are involved, in a nontrivial manner, in the design of the algorithms and in writing the corresponding code.

The proportion of faculty in class 4 is quite small, and the distribution is skewed heavily toward the younger staff.

Clearly there is a "continuing education" problem of unprecedented magnitude which is exacerbated by the rate at which computer technology is evolving. This constitutes the greatest barrier to realization of the potential of computer-enhanced informational technology in research. Furthermore, our institutions are so organized that the mechanisms available to relieve that problem are inadequate.

Sophistication of the Administration

Ever since the ubiquitous computer appeared on campus, administrators have had to wrestle with the following:

- The seemingly insatiable demand from the administrative record keepers/report generators, and from the researching faculty, for larger, faster, more interactive systems.
- Administrators' lack of formal computer training, comprehensive first-hand experience with computer use, or personal involvement in computing. Hence their policy making in this regard must be based on others' impressions.
- The uncertainty, indeed the seeming capriciousness, of the federal funding agencies regarding computing support for research and instruction.
- At the state level, resource sharing via networking that at one time was impressed on some or all of the state supported institutions in some states.
- The continuing expansion of the range of computer applications.
- Continuing miniaturization and decrease in the price of computing hardware that enable individual researchers to meet an increasing fraction of their research computing needs with their own computers.
- Availability of an increasing number of sophisticated computer-based off-campus services.
- Automation in the libraries.

Budgeting Policy

When the computer first appeared on the university campus it was expensive and constituted a new kind of phenomenon: a campus research facility that cut across all departments, schools, and colleges but whose potential for enhancing research was poorly understood. Furthermore the computer could operate twenty-four hours per day, seven days a week, and its users seemed to be willing to bend their work schedules out of shape in order to make full use of that resource.

Several complications gradually developed. U.S. Circular A-21 seemed to insist that externally sponsored research, paid for by the U.S. government, would be billable for machine time at a rate roughly equal to the total cost of operating the facility divided by the number of billable hours it was used. Thus, if machine time (that would otherwise not be used) was made available for nonexternally sponsored research, the charge per hour which could be levied against externally sponsored work was reduced. Furthermore, once a commitment had been made to an internal computer-based service facility, the administration was reluctant to permit the campus community to purchase computer-based services elsewhere. Thus, many universities developed three complementary policies, namely:

- All computing shall be done at the campus computer center, particularly externally sponsored computing.
- No researcher or academic department shall buy, or otherwise acquire, its own general purpose scientific computer. (In some cases the restriction applies to all computers.)
- Campus computer time shall be allocated under a "funny money" system. The potential billable time for the campus computer for a particular fiscal year was estimated, that fraction to be used for externally sponsored research estimated, and the remainder translated into scrip which was distributed in a variety of ways to potential users. Scrip, or "red" dollars, could be used only for campus computer center services in contrast with real money, or "green" dollars, which could be spent anywhere.

The abrupt change in federal funding policy about the time of the 1969-70 *Inventory of Computers in Higher Education,* together with the mild recession of the early '70s, led to a severe hardening of university restrictive policies regarding computing for research. This happened in spite of the fact that computing technology was steadily decreasing in cost while increasing in power and ease of use, and in spite of the fact that sophisticated users were gradually emerging on many campuses. The policies currently in place, de facto or de jure, vary widely across higher education.

Table 6.1 summarizes expenditures for computing to support researchers identified by inventories in 1969-70 and 1976-77. To provide some perspective, Figure 6.1 reproduces the U.S. Department of Health, Education, and Welfare March 1979 "American Education" statistic of the month which summarizes total expenditures for research by colleges and universities. In summarizing the data, it was assumed that the predominant use of computers to support research was within doctorate granting institutions. Judging from the two surveys, it appears that about 40% of faculty research computing in public doctoral universities was externally sponsored during 1969-70 and dropped to less than 30% in 1976-77. For private institutions, the percentage was 53% for 1969-70. In absolute number, 165 of 177 public universities responded to the 1969-70 survey, and 152 of 207 responded in 1977. Among private universities, the response rate was 122 out of 163 in 1970, and 132 out of 215 in 1977. The 1976-77 billing at doctorate institutions was distributed as follows among those installations reporting on this survey item:

Campus utility: Budgeted	52%
Cost center: "Red" dollars	29%
Cost center: "Green" dollars	19%

Thus about 20% of the universities now include computer time in the regular academic departmental budgets. Presumably, in some cases, departments can purchase off-campus computer services, or departmental minicomputers, if they so desire.

Researchers doing experimental work, particularly that which is externally sponsored, have relatively little difficulty in acquiring their own minicomputers to be used for real-time computing such as data logging or laboratory control. Furthermore, the

Table 6.1

Summary of Reported Research Computing Expenditures of Public vs. Private Doctoral Level by Discipline 1966-1967 and 1976-1977

Discipline	Research Use Dollars (millions)			
	Public/Doctoral		Private/Doctoral	
	69/70	76/77	69/70	76/77
Engineering	7.1	15.7	8.7	*
Envir & LS	8.5	12.0	4.0	*
Comp Sci	3.2	4.0	3.9	*
Math Sci	1.2	3.8	.5	*
Phys Sci	12.0	40.7	7.2	*
Psych	1.2	2.1	1.2	*
Soc Sci	2.3	6.8	2.8	*
Edn	1.0	2.6	.6	*
Bus & Comm	1.3	4.0	1.1	*
All Other	7.0	14.5	5.0	*
Totals	44.8	106.2	35.0	*
% Sponsored	39	28	53	*

* Insufficient data reported

*For comparison with 76/77 the entries in 66/67 for Agri Forest, Arch City plan, Bio Sci and Health Sci were collected and called Env & LS

Figure 6.1
Statistic of the Month

Expenditures for Research by Colleges and Universities for Fiscal Year 1977

Colleges and universities in the United States differed widely in the emphasis they placed on research and the amount of money spent for this purpose during fiscal year 1977, according to a recent survey by the National Center for Education Statistics. The ten universities that led in expenditures for research were:

	(In millions)
University of Wisconsin, Madison	$ 93
Stanford University (CA)	82
Massachusetts Institute of Technology	78
Columbia University, (NY)	76
University of California, San Diego	70
Harvard University	69
University of California, Los Angeles	67
University of Washington	65
University of California, Berkeley	64
University of Minnesota, Minneapolis-St. Paul	62
TOTAL	$728

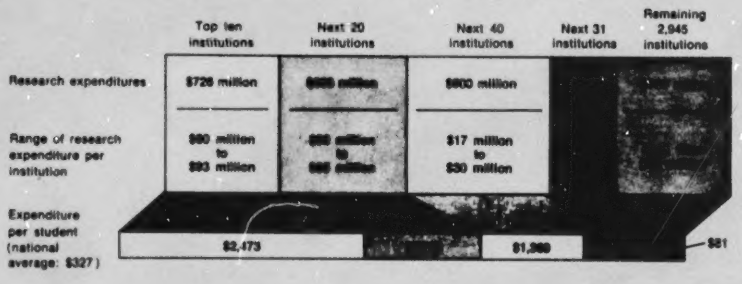
The next 20 universities, research-oriented to a considerable extent, spent between $30 million and $60 million each on research, totaling $833 million. The institutions ranking 31st to 70th, moderately research-oriented, spent between $17 million and $30 million each on research, for a total of $900 million. The marginally research-oriented group ranking from 71st to 101st spent from $10 million to just under $16 million each, for a total of $401 million. (A listing of all institutions spending more than $10 million each for research during fiscal year 1977 is available from the Statistical Information Branch, National Center for Education Statistics, Washington, DC 20202.)

The remaining 2,945 colleges and universities spent a combined total of only $740 million and have not been ranked.

The institutions spending more than $10 million each for research were predominantly universities, 55 of which were public and 26 private. Eleven of those institutions were four-year branches of universities. Only nine were other four-year colleges. None were two-year colleges.

—C. George Lind
Specialist in Education Statistics

Expenditures of $3,600 million for research by the 3,046 institutions of higher education



scientific instrument manufacturers are incorporating microprocessors and associated digital-logic-based devices directly into the design of their products. Once such devices are in place to support experimental work, it is difficult to control their proliferation through budgetary control, particularly with the advances being made in computer networking technology.

Evolution of Computer Hardware

During the ten years since the 1966-67 *Inventory of Com-*

puters in Higher Education,[2] four trends are discernable which have influenced the computer in higher education.

Large scale scientific computers. By and large there has been very little significant change. The IBM 360 line evolved into the 370 line and, at the top end, the 360/91 and the 360/195. Now the IBM 3000 and 4000 series have been announced. Amdahl entered the picture at the top end of the IBM line but without seriously impacting the scientific computer power there. CDC's 6400, 6600, and 7600, the number crunching stalwarts of yesteryear, have been slightly upgraded with a new name, the Cyber series. The BSC and the CRAY 1 have appeared but have spread slowly. The scalar arithmetic problem of the STAR-100 slowed down its acceptance. The CRAY people see a market for twenty of their devices.

At NASA Ames Research Center there is a perceived need for a number cruncher to support a numerical wind tunnel algorithm, the total system to have eighty times the throughput that algorithm would have on the CDC 7600. Two corresponding feasibility studies by Burroughs and CDC show that it can be done.

Thus there is revealed the interesting question: are the vendors not marketing supercomputers 100 times the capacity of the CDC 7600 because the user community does not have socially relevant problems which depend in an essential manner on such computing power, or is there a discipline-oriented self-organizational problem with regard to making those needs known. At any rate, it is clear universities are operating at a level which is far short of the potential of today's technology for large-scale scientific computing. It is also clear that no university can afford to own a modern supercomputer.

Superminis. Table 6.2 is a chart from a recent issue of *Computer World* which displays the basic features of a number of so-called "super" minicomputers or superminis. The low-end cost figure should be multiplied by 2 or 2.5 in order to arrive at a reasonably "full-blown" configuration. DEC's VAX, for example, in its high-end manifestation provides scientific computer power at the level of the CDC 6400 or perhaps the CDC 6600. Monthly maintenance is about 1% the purchase price and users who can handle a comprehensive remote job entry station to

Table 6.2
Features of Super Minicomputers

System / Characteristics	Prime 650	Prime 750	Harris 570	Perkin-Elmer 8/32	Systems Engineering Laboratories 32/77-60
Word Length (Bits)	32	32	24	32	32
Instruction Length (Bits)	48	48	24	48	64
Main Memory Cycle Time (Nsec)	600	600	300	750	900
Main Memory Maximum Capacity (Bytes)	8M	8M	2M	1M	4M
Cache Capacity' (Bytes)	2K	16K	2K	Not Available	Not Available
Virtual Machines?	Yes	Yes	Yes	No	No
Floating Point Standard?	Yes	Yes	No	No	No
Low-End Configuration					
Main Memory	256K Bytes	256K Bytes	2M Bytes	512K Bytes	512K Bytes
Disk Capacity	32M Bytes	32M Bytes	300M Bytes	10M Bytes	80M Bytes
Other Hardware	Console	Console	Console; Tape; Communications	Console; Tape	Console; 75 in./Sec Tape; 600 Line/Min Printer; 300 Char/Min Reader; Register Transfer Modules
Software	Primos	Primos		OS-32, FORTRAN Utilities	
Low-End Cost	$95,000	$130,000	$276,000	$89,900	$109,900

Source: International Data Corp. Adapted with permission.

Table 6.2 Continued

Characteristics \ System	DEC PDP-11/70	DEC VAX-11/780	DG M/600	HP 3000-111	Honeywell 6/57	Univac V77-800
Word Length (Bits)	16	32	16	22	16	16
Instruction Length (Bits)	16	32	32	64	48	16
Main Memory Cycle Time (Nsec)	1,000	600	800	700	550	600
Main Memory Maximum Capacity (Bytes)	2M	2M	2M	2M	2M	2M
Cache Capacity (Bytes)	2K	8K	Not Available	Not Available	8K	1K
Virtual Machine?	No	Yes	No	Yes	Yes	No
Floating Point Standard?	No	Yes	Yes	Yes	No	No
Low-End Configuration						
Main Memory	256K Bytes	256K Bytes	256K Bytes	256K Bytes	128K Bytes	256K Bytes
Disc Capacity	176M Bytes	56M Bytes	50M Bytes	50M Bytes	10M Bytes	60M Bytes
Other Hardware	Console; Tape	Console	Console; Tape; Printer	Console; Tape	Console; 300 Line/Min Printer	Console; Tape; Line Printer; Eight CRT Terminals
Software	RSX-11M	VAX VMS	AOS	OS Languages		Summit
Low-End Cost	$101,000	$128,000	$121,000	$105,000	$80,000	$135,000

Source: International Data Corp. Adapted with permission.

use a remote computer should be able to operate the supermini without any great difficulty. Thus, CDC-6400 equivalent scientific computing power is available to the scientific researcher at about $15 per hour direct incremental cost.

Laboratory Minis. A wide range of laboratory minicomputers is available to support scientific research. Beginning with the rack mountable DEC PDP-8 of many years ago, these devices have evolved from bare hardware with small instruction sets, short word length, and no peripherals to sophisticated and inexpensive devices with operating systems, higher level languages, A/D and D/A converters, and low-cost peripherals including mass storage devices. Out of the DEC-11 family has emerged the microprocessor-based LSI-11 which will execute the basic DEC-11 instruction set and provide inexpensive access to more and more of the DEC-11-based software. Within DECUS, the DEC computer users' group, the LSI-11 discussions are among the liveliest and occur in increasing numbers.

The cost of a comprehensive laboratory minicomputer is no longer considered a major equipment expenditure item. They are being acquired in increasing numbers and treated just like any other instrument. In particular, no one really worries any longer about whether or not all the machine cycles are being used any more than one worries about whether or not an infrared spectrometer is being used around the clock—seven days per week.

A device based on an LSI-11 can be purchased for about $3,000. One can purchase an LSI-11 with 32K 16-bit words and a 5 megabyte hard disk for less than $10,000.

Personal Computers. A number of years ago, large-scale integrated circuits began to be mass produced for use in computers. A direct side effect was the hand-held calculator industry which flourished during the 1960s and which came to provide the semiconductor industry with a high volume market for logic components. By February 1971 Mostek developed the first single-chip calculator, on a single chip of silicon. The first microprocessor, the Intel 4004, was announced just nine months later. It was designed to be a complete powerful central processing unit on a single chip and would interact with two memory silicon chips, one Read Only Memory (ROM) and one Random Access

Memory (RAM), to form a stored-program microcomputer system. It now sells for $5.

Since that time, the microprocessor has come to be widely used, and wide usage has led to a richness of applications, to reduction of cost, and to the beginning of standardization. All of these effects auger well for scientific research. Personal computer manufacturers have come into being. These devices are well-engineered and reliable total systems. They include hardware, software, and system growth potential. A single such system (purchased for about $2,000) can function in three modes:

- As a computer terminal communicating in ASCII via an RS232C port.
- As a stand-alone computer with thirty or forty KB of semiconductor memory and a sophisticated extended BASIC language.
- As real-time computer with a parallel interface and a sophisticated assembler with comprehensive diagnostics.

Furthermore, inexpensive applications software is becoming increasingly available including word processors and graphics packages. The quantum of scientific computing has gotten sufficiently small so that the choice, as well as the computer, is in the hands of the user.

Evolution of Computer Software

Computer software is interpreted in this chapter as general purpose user-oriented systems for research excluding software dedicated to specific classes of data bases.

Clearly the research computer user would like to have a cost-effective interactive system which communicates via a familiar problem-solving language and notation including an effective graphics display. Collection and organization of data ought to be automatically handled by the system working from the statement of the problem. Clearly it would also be highly desirable to have a range of problem-solving tools available in the system based on algorithms which are state of the art, optimal for the particular system architecture in use, simple to call, and thoroughly tested and certified. Clearly university researchers today are far short of that objective.

Today researchers have FORTRAN. They have had FORTRAN for many years. Any attempt to introduce a language other than FORTRAN is stopped short because:

- Users already know FORTRAN and are unwilling to learn another language.
- There is a large investment in software written in FORTRAN. That would be lost if a new machine were brought in which would not "understand" FORTRAN.
- Universities and colleges continue to teach aspiring engineers and scientists to program in FORTRAN.

The recently announced FORTRAN '77 merely codifies features the principal vendors incorporated long ago.

Scientists develop algorithms for specific problems on which they happen to be working. Many of those algorithms could be used in other problem areas by other scientists. Program exchanges have come into being: COSMIC at the University of Georgia; the Quantum Chemistry Program Exchange at Indiana University; SHARE, an IBM user group; DECUS; etc. Their success has been uneven; certified software is conspicuous by its absence. Some specific software packages of interest to scientists exist and are relatively well known, for example, the International Mathematical and Statistical Library, EISPACK from Argonne National Laboratory, and the statistical packages SPSS and BMD. IBM's SSP (Scientific Subroutine Package) has been around for a long time and suffers from an image problem, although it is obviously useful for the neophyte.

The question is: How far along are university research scientists in getting from standard scientific computing to the ideal? Several trends, which evolved during the past decade of interest, indicate some progress toward the ideal.

First there is the development of SPEAKEASY.[3] SPEAKEASY was initiated at Argonne National Laboratory by Stanley Cohen in order to facilitate the use of a major computer for research in theoretical physics. He felt that the service computing facility as then organized was not meeting his needs. Gradually some of his colleagues began to use his system, and they were followed by other groups elsewhere. A users' group evolved with annual meetings that were national in scope. Eventually, Cohen stopped doing physics research, left Argonne, and formed a for-profit company to further develop and market the SPEAKEASY system.

SPEAKEASY was designed for humans to use. All user control input is free from jargon and composed of easy-to-remember English words and a few symbols whose meanings come from a natural notation. Thus, the control syntax is easy for infrequent users to learn and to remember. The package can be extended to fit the needs of a particular computer installation. The user's own routines can be mixed freely with those supplied by Cohen. In fact, the users' group is a source of routines as well as a source of additional vocabulary. Any extension made at one site is transportable to another.

The system carries three levels of documentation for each routine in the repertoire. SPEAKEASY runs interactively, or in batch, and it is written in FORTRAN. It is most useful for development work or to satisfy occasional scientific computing needs. SPEAKEASY is a distinct milestone on the road toward moving the human-machine interface closer to the human.

Another trend is the growing realization that large-scale scientific computational enhancements will arise from using highly concurrent multiprocessor systems operating on highly organized data streams viewed as vectors and matrices. Acceptance of corresponding FORTRAN extensions has been slow. Considerable effort has been expended to place the full burden of vectorizing FORTRAN programs on the optimizing compiler. Although considerable progress has been made on the theory of compilers required to convert FORTRAN to efficient vector-oriented machine code, this approach is not sufficiently advanced for practical use with current or planned vector computers.[4] At the present time, the most flexible and convenient extended FORTRAN language for vector processing appears to be that of the Texas Instruments Advanced Scientific Computer.[5] SL/1 (STAR Language 1), developed for the STAR computer at NASA Langley Research Center, is most closely related to PL/1.

Finally, for the experimentalist interested in real-time computing there has appeared promise of relief from having to program their own very fast routines in a simple low-level language. An indicator of significant progress in this regard is MICRODARE, a direct-executing software system which permits users to program their own very fast routines in a simple high-level language, without any need to learn assembly language. Indeed, if one microcodes those routines for the new microprogrammable LSI-11 microcomputers, the MICRODARE programs will execute faster than when written in assembly language.[6]

With regard to graphics, N. Norton Wise, an historian, demonstrates through an important case study how scientific imagination has been guided by visual images.[7] He says, "The process of Maxwell's creation is of considerable interest for the history of science because it illustrates simply and clearly the importance of pure imagination. Maxwell was, at this time, neither a sophisticated mathematician (although his talent was great) nor an experimentally or theoretically learned electrician."

As new computers are produced which can process more and more numbers faster and faster, it becomes increasingly important to summarize in human understandable forms. Computer-generated graphics provide a solution. Although the levels of sophistication of image processing and pattern recognition on the one hand, and computer graphics generation on the other, have been brought to impressive heights, the cost is still very high and the ease of use by the problem solver not sufficiently evolved for these computational aids to have a broad impact on research in higher education.[8]

Evolution of Interuniversity Resource Sharing

According to H. Shull, there are over 500 interinstitutional organizations of universities.[9] Presumably these exist because someone has perceived some benefit to be derived from institutional cooperation and/or some sort of resource (such as information) sharing. The number of informal arrangements between two or more individual researchers on two or more campuses must be substantially larger.

With the evolution of more—and more expensive—instrumentation needed to support research, formal arrangements for regional centers are being encouraged by NSF and other research-supporting federal agencies. Computer-based resources represent only one of many classes of expensive research instrumentation.

The sharing of computer hardware (and the usual utility software) presents an interesting situation. With the rapid evolution and decrease in cost of super minicomputers (as well as personal computers), the pressure to share expensive supercomputers has been relieved. An important consideration is that basic research generally involves "proof of concept" rather than extensive application or developmental use of computers. Accordingly, until such time as research scientists develop models which require very large-scale supercomputers for "proof of concept," the sharing of large-scale computer hardware per se is not likely to constitute a major research need.

Another reason for hardware resource sharing via remote access is to provide access to specific data bases and corresponding algorithm sets which would be nontransportable to the user's local facility for some technical, political, and/or economic reason. This would constitute the most basic and least politically sensitive form of resource sharing, and the EDUNET[10] system, now completing its first five years of activity, represents the first comprehensive attempt at computer-based interuniversity resource sharing. The real significance of EDUNET is that prestigious universities took the initiative, and were willing to commit their own funds and the time of some of their key people, in order to put into place a functioning network and give the much discussed concept an opportunity. The next five years will tell the story.

Evolution of Federally Supported National Computing Resources

There exist several examples of federally supported national computing resources to support research in some discipline or problem area.

The National Center for Atmospheric Research (NCAR), Boulder, Colorado, has perhaps the longest history of operating a major computer-based resource that, by policy, had a significant fraction allocated to university-based researchers. NCAR, supported by NSF, has continually upgraded its scientific computing power. As its computer systems evolved with CDC to the 7600 (subsequently adding a CRAY I), NCAR also evolved its capability to support remote access users. Atmospheric research cuts across a number of disciplines in science and applied science, so NCAR must be considered as a problem-focused multidisciplinary laboratory.

The Magnetic Fusion Energy Computing Center is a Department of Energy (DOE) supported facility which was designed to provide significant remote access scientific computing power, as well as a problem-solving forum, for researchers in universities and federal laboratories. Magnetic fusion energy researchers are geographically distributed over the United States. The principal computing facility is located at Lawrence Livermore Laboratory (LLL) and is physically distinct from the secure LLL intralaboratory computer network.

The most recently commissioned discipline-oriented national computational resource is the National Resource for Computation in Chemistry (NRCC). The NRCC evolved over a period of years until, finally, with joint NSF-DOE support it entered Phase I of its existence in October 1977 housed at Lawrence Berkeley Laboratory contiguous to the University of California, Berkeley. The initiative for the NRCC came from the quantum chemists who compute the properties of molecules from the laws of physics. Since there are 4.5 million unique molecules described in the literature, and the number is increasing at the rate of 300,000 per year, it is clear that quantum chemists (and those who use their computer-based systems) could use enormous amounts of scientific computing power. In addition, chemical reactivity, as well as the properties of bulk matter from a molecular perspective, are proving amenable to scientific computation. Clearly, physical chemists can substantially enhance their research through sharing massive computing power (which would not otherwise be available to the workers in the cottage industry that chemistry is) and more importantly, their problem-solving methods. Because of a slow start, Phase I of NRCC development was extended one year without an increase in total support. Thus, by 30 September 1981, chemists should know whether or not this discipline-oriented computation-based resource will succeed.[11]

A somewhat complementary activity is the Institute for Computer Applications in Science and Engineering (ICASE) based at Langley Field, Virginia. ICASE is supported by NASA and provides a focus for algorithms development that relates to NASA concerns. ICASE is operated by the Universities Space Research Association (USRA). Although USRA has a small permanent staff, research is done primarily by visiting scientists from universities and industry who have resident appointments.[12]

For many years the National Institutes of Health supported the Health Sciences Computing Facility based at the University of California, Los Angeles. A principal focus there was the development and continuing evolution of a statistical software package, BIOMED, which has seen very wide use in the life sciences and elsewhere.

There is a spectrum of federally supported national computing resources. Some are broad in their range of concerns, others are quite focused. Some provide computer services, others focus on algorithm development. To date they do not appear to have had a major impact across the entire range of university-based research activity.

Sophistication of the Problem-solving Disciplines

Clearly there is a gap between the rapidly evolving technology and the extent to which its potential in research is being realized and that gap is growing rather than shrinking. Clearly the lost opportunities are being felt by research scientists outside of academe as well as those within. Higher education has failed to meet its assumed responsibility in this regard for its own faculty as well as for its clients.

A possible way out of this dilemma is for the discipline-oriented national organizations such as the several sections of the National Academies of Sciences and Engineering and corresponding professional societies to take the initiative in a structured manner. With their network of conferences, publications, and continuing education programs, the professional societies are in a particularly good position to take the responsibility for widespread education of research scientists regarding computing.

For example, societies might follow the lead of the International Union of Pure and Applied Chemistry which will consider a petition from members in September 1979.[13] The petition reads as follows:

> The large and very rapidly growing influence of the ubiquitous electronic digital computer in the practice and in the teaching of chemistry has created a need for chemists all over the world to share corresponding information and experiences.
>
> When computers first became commercially available in the middle 1950s, they came to be used by many scientists and engineers. Some of those users fostered a new academic discipline, computer science, and for many years problem solvers and decision makers were content to leave the evolution of and teaching about computer systems in the hands of computer engineers and scientists.
>
> Chemistry, as a discipline, began to organize itself in this regard and is thereby able to have a more structured reaction to the impact of the computer. Within the United States, the National Academy of Sciences formed a new standing committee in 1966, Computers in Chemistry, and out of that beginning there emerged four significant developments:
>
> 1. The first International Conference on Computers in Chemical Research and Education was held at Northern Illinois University in July 1971. Sixty papers were presented and proceedings distributed. The most recent such conference, the fourth in the series, was held in Novosibirsk, USSR, in July 1978. (The second happened in Yugoslavia in 1973, the third in Venezuela in 1976; all had published proceedings.)
>
> 2. The American Chemical Society formed the Division of Computers in Chemistry (COMP) in April 1974. Since that time, COMP has conducted (and published) many symposia dealing with some aspect of computers and chemistry.
>
> 3. The NRC Committee on Computers in Chemistry organized a workshop on computational support of theoretical chemistry. That started a series of events which led to the creation of the National Resource for Computation in Chemistry. The U.S. Department of Energy and the National Science Foundation supported (equally) Phase I (3 years) of the National Resource for Computation in Chemistry which began operation 1 October 1977 at Lawrence Berkeley Laboratory.
>
> 4. The American Chemical Society has decided to affiliate

> with the members of the American Federation of Information Processing Societies (AFIPS) which has as one important function the annual self-supporting National Computer Conference (NCC). In June 1978 the week-long NCC drew 57,000 participants, had many parallel sessions of technical papers and 1,000 booths rented for an associated exposition. In addition it contained a large national personal computing fair. The NCC provides an important forum for those who wish to learn about recent hardware/software developments, which are evolving very rapidly, and of their applications. Computational chemists could become involved in defining the NCC technical program as well as drawing the attention of many other chemists to this much needed and valuable forum.
>
> At the Fourth International Conference on Computers in Chemical Research and Education held in Novosibirsk, USSR, July 1978, participants from several countries discussed the need for a more formal and structured mechanism for fostering cooperation and the sharing of information and experiences regarding computers and chemistry at the international level.
>
> The International Union of Pure and Applied Chemistry, which would seem to be the appropriate organization, does not, at the moment, include an administrative entity such as a Commission of Chemical Informatics. Such an entity could accommodate the entire range of problems/opportunities of collecting, storing, processing and interpreting of data for chemistry, controlling chemical processes in real time, and computing the properties of matter from the laws of physics.

The symposia referred to in the foregoing quotation (item 2) conducted by the ACS Division of Computers in Chemistry over the past five years cover a wide range of applications of computing to chemistry. Proceedings have been published by the American Chemical Society on half of those topics: computer networking and chemistry; computer-assisted organic synthesis; algorithms for chemical computation; chemometrics: theory and application; minicomputers and large-scale computations; computer modeling of matter; computer-aided drug design; and personalized computing and chemistry. Other topics were considered but not covered in special separate publications: program certification and transferability; graphics: input and display; micros and minis in education and research; laboratory automation; microelectronics and chromatography; reaction mechanisms, models and computers; chemistry and biology data bases, and process control. In addition other ACS Divisions such as Chemical Information Systems and Analytical Chemistry have been very active in their respective areas of concern in computer applications. Thus the chemistry establishment has reacted to the computer impact on research in chemistry in a comprehensive and structured manner. Disciplines other than chemistry have responded as well—but none to that extent.

The computer-based numerical methods research community has developed a report, *Numerical Computations: Its Nature and Research Directions,*[14] which covers in detail six major areas: linear algebra; optimization and nonlinear equations; ordinary differential equations; partial differential equations; mathematical software; and curves, surfaces, and graphics. In addition, eight other important areas are covered as well as a discussion on the environment for research in numerical computation. Thus the computer science community is reaching out to researchers in other disciplines—a good sign.

Summary

In summary, computer hardware and software technology is evolving faster than the ability of university-based researchers to realize its potential. Furthermore the broad range of affordable hardware is enabling noncomputer scientist researchers to design and build their own systems. In the process many are reinventing the hardware and software systems of yesteryear. Ontogeny recapitulates philogeny. Very large scale supercomputers will not be located on university campuses and will not be easily accessible to qualified university researchers unless explicit cognizance is taken of this need at the national policymaking level. Super minicomputers will continue to proliferate and will be adequate for most "number crunching" support needed for "proof of concept." Laboratory use of microprocessor-based systems is expanding at a very large rate with the LSI-11 providing a de facto standard and basis for program exchange. Software tools are evolving gradually with significant contribution from the user community. Infusion and diffusion of modern computer-based methods in research will take place in direct proportion to the extent that discipline-focused professional societies and related groups take the initiative to self-organize and undertake action programs in this regard.

Notes

1. John W. Hamblen, *Inventory of Computers in U.S. Higher Education, 1969-70* (Washington, D.C.: U.S. Government Printing Office, 1972).

2. John W. Hamblen, *Inventory of Computers in U.S. Higher Educaton, 1966-67* (Washington, D.C.: U.S. Government Printing Office, 1970).

3. Stanley Cohen, "SPEAKEASY—A Window Into a Computer," NCC 76 *Conference Proceedings*, AFIPS, Vol. 45 (1976):1039-47.

4. D. J. Kuck, *ACM Computing Survey* 9 (1977):19

5. *Description of the ASC System*, Part I-V (Austin: Texas Instruments, November 1975).

6. G. A. Korn, "MICRODARE: A Fast Direct-Executing High-Level-Language System for Small Computers," *IEEE Computer 1979*, to be published.

7. N. Norton Wise and W. N. Wise, "The Mutual Embrace of Electricity and Magnetism," *Science* 203 (March 30, 1979):1310-18.

8. Joint ACM SIGRAPH/IEEEE Computer Society Computer Graphics and Pattern Recognition and Image Processing Conference, Hyatt Regency O'Hare, Chicago, August 6-10, 1979.

9. H. Shull, Networks and Disciplines, EDUCOM CP 272 (1973):148.

10. For more information on EDUNET, write the EDUNET staff at EDUCOM, P.O. Box 364, Princeton, N.J. 08540, or telephone (609) 921-7575.

11. *NRCC Bulletin* 11, (April 1979), LBL, CA 94720.

12. ICASE, Semiannual Report, April 1, 1978–September 30, 1978, NASA Langley Research Center, Hampton, VA 23665.

13. Petition to be considered by the IUPAC Division Presidents Meeting as part of the IUPAC General Assembly, Davos, Switzerland, September 1979.

14. SIGNUM Newsletter, Special Issue "Numerical Computation: Its Nature and Research Directions," ACM, P.O. Box 12105, Church Street Station, New York, N.Y. 10249.

7

Computing in Minority Institutions: 1976-77

Jesse Lewis, Clinton Jones,
Patricia Marshall, and John W. Hamblen

Definition

Minority institutions are defined in this study as those accredited institutions with approximately 50% or more of their students from one or more socioeconomically disadvantaged ethnic backgrounds[1] (Black, Hispanic, American Indian, Hawaiian). The 228 minority institutions identified enrolled a total of 743,810 students.[2]

Dominating the sample are the predominantly Black institutions (see Figure 7.1) that constitute 71.5% of the 228. At the time of the study these included both the 105 traditionally Black schools (most four-year institutions, some of whose histories span a century or more) and 58 schools formed more recently for a total of 163. These latter, chiefly urban based, include a large number of two-year colleges; approximately 20%

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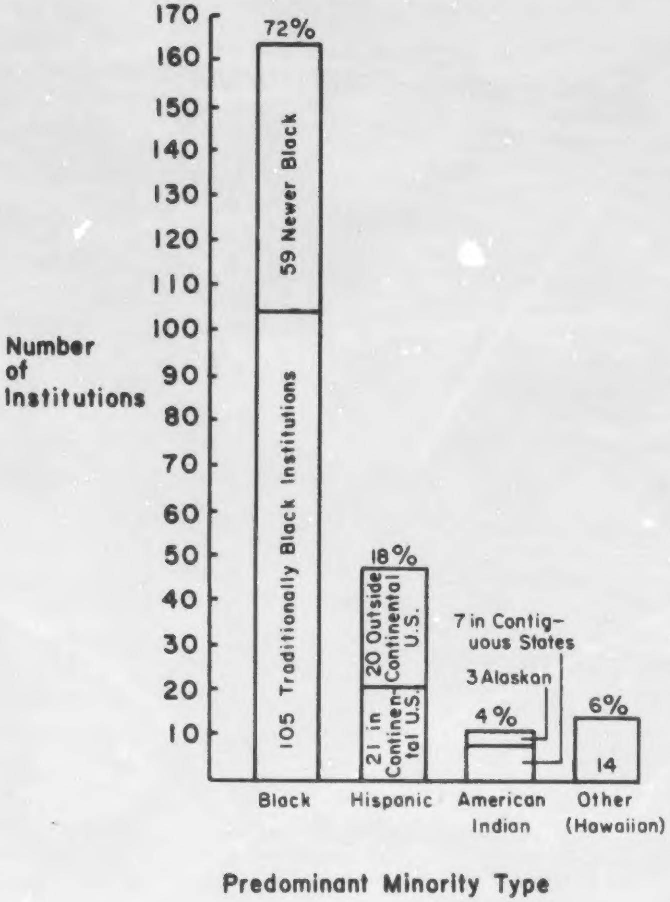
Figure 7.1
Numbers of
Minority Institutions
Fall, 1975



Source: National Center for Educational Statistics in U.S. Dept. of Health, Education, and Welfare.

of them also include fairly sizable proportions of students with Hispanic origins.

The predominantly Hispanic institutions include twenty-one in the continental United States, nineteen in Puerto Rico, one in the Virgin Islands, and one in American Samoa. The American Indian institutions inlude Eskimo and native Alaskan schools. They numbered ten at the time of the study (mostly community colleges), three of which are in Alaska. Others exist but were not included in data reported by the National Center for Educational Statistics because they were still in the process of organization. Institutions categorized in this study as "other" are Hawaiian, and they numbered thirteen.

Enrollment Profile

Since the nonblack institutions made up a relatively small portion of the total minority insitution sample (Figure 7.1), little attempt has been made to differentiate among the minorities at this point with regard to interpreting the data. Of greater significance are the differences in enrollment among institutions categorized by highest level of offering (Figure 7.2) and by enrollment categories (Figure 7.3). The largest difference in enrollment occurred (as is evident from Figures 7.2 and 7.3) between private minority institutions (enrolling 137,623 students, or 18.5%) and public (enrolling 606,187 students, or 81.5%). Another significant fact is shown by Figure 7.2: More than half the students in minority institutions were in schools whose highest degree was the associate; and 91.5% of these students were in the public institutions (most of which are relatively new). It appears that the newer institutions (mostly public, two-year, predominantly black or mixed schools) enroll many more students than most of the older institutions.

FICHE Response Rate

The percentage of minority institutions responding to the FICHE survey was close to 51%, which is roughly comparable to the 58% overall response rate. The fact that it is a little lower probably reflects the commonly overcommitted situation with

Figure 7.2
Enrollment of Minority Institutions
by Highest Level of Offerings
1975

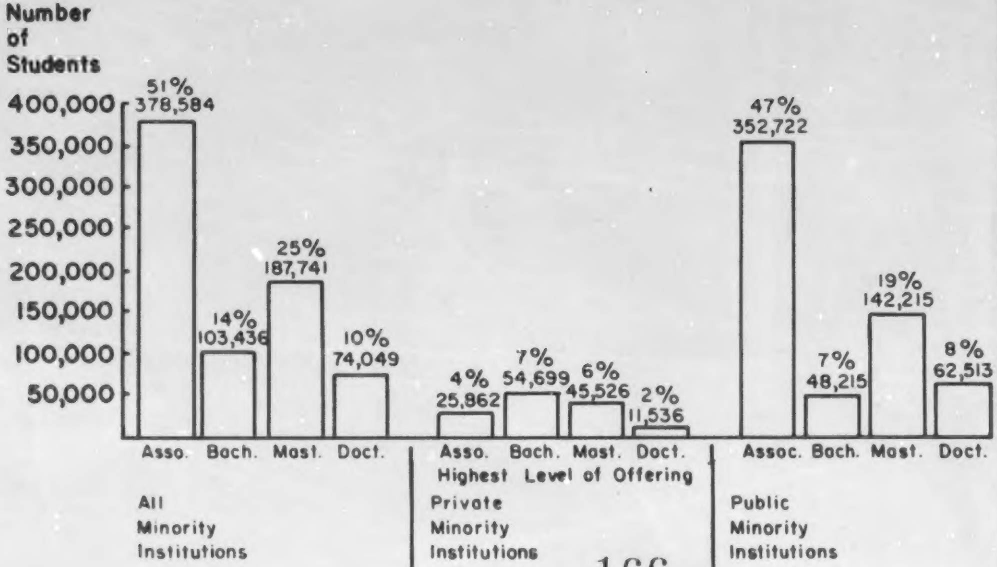
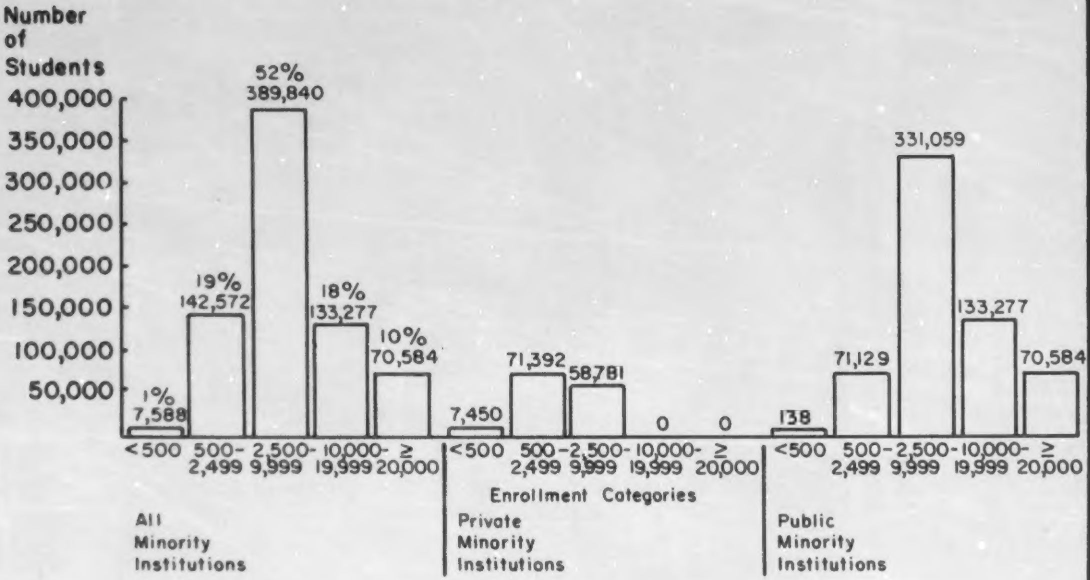


Figure 7.3
Enrollment of Minority Institutions
by Enrollment Category
1975



regard to personnel in minority institutions, as well as less experience with the FICHE forms.

Computing Installations

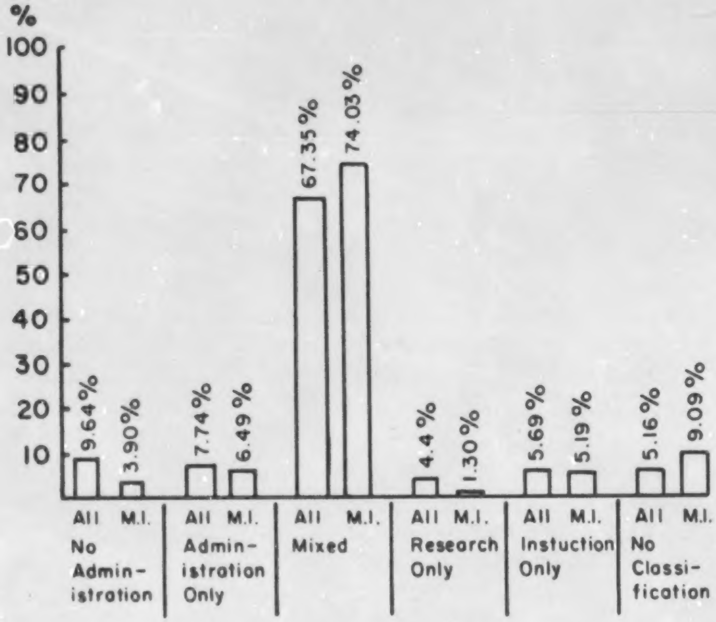
Officer to Whom Installation Reports

Nationally the pattern of officers to whom the computing installations report is somewhat random, and the minority institutions are not significantly different in this respect. As was the case with all institutions, the three highest reporting levels were (a) the head of the institution or campus (28.5% in minority institutions, 19.51% in all institutions), (b) the chief business officer (19.48% in minority institutions, 25.89% in all institutions), and (c) the chief academic officer (16.88% in minority institutions, 17.61% in all institutions). Minority installations tend to lean a little more heavily toward reporting to the head of the institution or campus and a little less heavily toward reporting to the chief business officer than did their nonminority counterparts. This may be because they have had the opportunity to observe the soundness of this approach from other installations serving both academic and administrative users. (Nearly three-fourths of the minority institutions use computers for multiple purposes.) On the other hand, the data may only reflect that large institutions in the total population can afford separate installations for their chief business officers.

Type of Usage

Nearly 75% of the minority institutions reporting were using their computers for multiple purposes (administration, instruction, and research), at the time of the study. Figure 7.4 shows that minority institutions follow the general pattern of all colleges and universities. It is safe to assume, though, particularly in view of the number of two-year institutions, that not much research usage occurs even in the multiple-purpose installations in minority institutions. "Research only" scored lowest in type of usage (only 1%). Next lowest were "no administration" (4%), "instruction only" (5%), and "administration only" (6%). No classification of usage was reported by 9%. Presumably in these

Figure 7.4
Percentage of Usage Type
All Institutions and
Minority Institutions



cases computers were still on order or computers had been in use for too short a time for the installations to have accumulated meaningful usage data. This picture, of course, reveals nothing of the total amount of usage, its quality, the quality of access of users, cost effectiveness, etc.

Hardware Profile

On the surface, the data on hardware existing on, or accessible to, campuses of minority institutions appears to show little difference from the picture on other campuses of comparable size. Nearly 30% of the minority institutions are estimated to have had no computing at the time of the study. For all institutions this percentage is 31%.

Although we are talking about somewhat small samples outside the Black institutions, it is of some significance that half the Indian institutions had no computing. Among Hispanic institutions approximately 19% had no computing. In addition, approximately 11% of the Black institutions and one of the thirteen Hawaiian institutions (a private institution) had no computing. Of the thirty-two minority institutions without computing, all but two were private, and more than 56% were Black.

An analysis of hardware acquisition dates shows that nearly two-thirds of the computers on minority campuses were acquired in 1974 or later. This suggests that minority institutions acquired computer hardware using federal funding available to them in such programs as AIDP (Advanced Institutional Development Program) from the Office of Education, Department of Health, Education and Welfare (HEW) or MISIP (Minority Institution Science Improvement Program) from the National Science Foundation (NSF). If this assumption is correct, it can be further assumed that approximately one-fifth of the federal funding might have come from NSF; between one-tenth and one-fifth of the computers were acquired chiefly as gifts (especially several small PDP 8-E's from the Digital Equipment Corporation) and the rest were funded by HEW. These assumptions are based partly on the type of hardware acquired and partly on the names of the installations. For example, names such as "Data Processing Center" and hardware such as IBM System 32 are not suggestive of scientific or academic usage that would be funded by NSF.

In general it appears that minority institutions have used the federal funding recently made available to them to play "catch-up" with regard to computer hardware acquisition. It does not automatically follow that either administrative or academic usage will quickly approach national levels; however, the data does suggest that minority institutions generally are following in the footsteps of the other institutions in most respects.

Uses of Computing

Administrative Computing

Table 7.1 highlights the administrative applications most frequently reported by minority institutions as computerized (at least those ranking as "top ten") and also shows the percentage of computerized applications that were batch and on-line. The group of applications most frequently computerized was admissions and records, with financial management applications following closely behind; this parallels the picture in the total population. As was true for all institutions, payroll was

Table 7.1
Administrative Applications Most Frequently Computerized in Minority Institutions

Rank	No.	Percent	Type of Administrative Application	Percent of Computerized Applications Reported As: Batch	On-Line
1	59	51.30	Class Rosters[1]	91.53	8.47
1	59	51.30	Enrollment Statistics[1]	94.92	5.08
2	58	50.43	Student Registration Process[1]	81.03	18.97
3	57	49.56	Term Grade Reporting[1]	92.98	7.02
3	57	49.56	Enrollment Reporting[1]	98.25	1.75
4	55	47.83	Term Student Records and Reports[1]	89.09	10.91
5	54	46.96	Course Add/Drop Processing[1]	81.48	18.52
6	47	40.87	Undergraduate Admissions Process[1]	80.85	19.15
6	47	40.87	Payroll[2]	95.74	4.26
7	46	40.00	Departmental Expenditures[2]	93.48	6.52
7	46	40.00	Financial Aid Accounting[2]	89.13	10.87
8	45	39.13	Student Ethnic Group Reporting[1]	95.56	4.44
8	45	39.13	General Fund Ledger[2]	93.33	6.67
8	45	39.13	General Fund Expenditures[2]	93.33	6.67
9	44	38.26	Tuition and Fee Accounting[2]	86.36	13.64
10	41	35.65	Schedule of Classes Preparation[1]	78.05	21.95
10	41	35.65	Accounts Payable[2]	92.68	7.32

[1] Admissions and records

[2] Financial Management

the most frequent financial application using the computer.

All computerized applications were overwhelmingly reported to be batch operations, even more so than in the general population. Nearly one-fourth (24.6%) reported no on-line usage at all. Another 23.8% reported only one use of on-line capability, and 8.7% reported two uses of on-line capability. More than 57% reported two or fewer on-line systems. In the top ten computerized applications shown in Table 7.1, the percentages of computerized applications that are on-line are quite small.

These data suggest that with regard to administrative applications, minority institutions are (a) following the footsteps of nonminority institutions and (b) at an earlier point of development on the continuum of computerized administrative applications, at least with respect to the data reported for 1976-77.

Academic Computing

Academic computing in minority institutions is similar to that in all institutions reporting. Differences seem to be mostly a matter of scale and experience.

The academic computing equipment at minority institutions is, for the most part, smaller and less modern than that of the total group. Although several institutions reported fairly large systems, most had small systems that did not support interactive terminals. Some minority colleges buy service from other institutions. The institutions providing the service are usually not minority institutions. However, there is one large minority time-sharing network that provides services to other minority and nonminority institutions.

Comparative Computer-related Expenditures

Since it has been observed that practically all minority institutions fall in the enrollment category of less than 10,000 students, it seems reasonable to compare data from minority institutions with those from nonminority (Non-M) institutions in the same enrollment and type of institution categories. The Non-M entries in Table 7.2 were obtained from the FICHE survey data by subtracting minority data elements from the corresponding data elements given for "All Institutions Reporting" and then obtaining the average expenditures per institution for

Table 7.2

Average Expenditures in Thousands of Dollars per Minority or Type Institution Compared to "Non-M" (Non-Minority) Institutions in Same Category or Type for 1976-77

Areas of Estimated Computer Related Expenditures	By Enrollment Categories						Type Institution* (<10,000)				All Institutions* (<10,000 Students) Reporting	
	Below 500		500 - 2499		2500-Above*		Private		Public			
	Min.	Non-M.	Min.	Non-M.	Min.	Non-M.	Min.	Non-M.	Min.	Non-M.	Min.	Non-M.
Hardware Purchases	11	17	45	57	178	99	72	81	142	71	117	76
Software Purchases	5	2	7	8	13	10	6	10	12	7	10	9
Building & Furniture	-	6	10	13	40	12	27	9	25	14	25	12
Computer Staff	6	45	53	63	162	164	103	99	115	116	111	109
Hardware Lease	-	36	26	39	137	107	95	67	87	77	89	73
Software Lease & Services	-	7	11	10	12	15	12	11	12	14	12	12
Other Operations	-	8	19	20	53	54	53	37	33	35	39	36
Off-Campus Services	2	7	42	35	92	196	42	69	92	91	68	79

*The enrollment category of (2500-Above) includes only those institutions with enrollments between 2500-9,999. For "Non-M" under private or public type institutions, as well as under All Institutions Reporting, only those institutions with enrollment up to 9,999 are included.

each computer-related area based on the number of institutions responding in that given area.

It can be observed from the table that for minority institutions with enrollments less than 2,500, the average expenditures in computer-related areas in 1976-77 were less than the average for Non-M institutions in the same enrollment categories for practically all areas reported except for purchases of off-campus services. In the enrollment range of 2,500-10,000 the average expenditure in a minority institution for hardware purchases was almost twice that of a Non-M institution; for off-campus services the average expenditure of a Non-M institution was more than double that of a minority institution.

The large differences in average expenditures in this latter area may be due to the fact that many nonminority institutions have been able to obtain their first computers during 1976-77. FICHE data indicate that 40% of the minority installations reporting supplied interactive computing and at the same time about 36% used remote computing services. For the nonminority installations the data showed that about 41% had interactive computing and 32% used remote computing services.

A final observation of average expenditures by public and private minority institutions reveals that average expenditures for hardware purchases, software purchases, and off-campus services in public minority institutions were approximately twice those of private minority institutions in 1976-77. This simple fact may be one reflection of the economic pressures being experienced by many private institutions, and particularly the minority institutions.

Expenditures by Degree Level by Enrollment by Type Institution

Table 7.3 shows computer-related expenditures per minority institution by degree level and enrollment categories (below 500, 500-2,499, and 2,500-9,999), with grouping by public and private institutions in the same categories. It is apparent from the table that the differences in expenditures by minority and other institutions are greatest for private minority institutions with master's degree programs and enrollments of 500-2,499. The data reflect that average minority institution expenditures

Table 7.3
Average Expenditure for Computing in Minority and Other Institutions by Control, Degree Level, and Enrollment Category

Group	Degree	Enrollment Category	Average (Thousands) Expenditure/Institution	
			Minority Institutions	Other Institutions
Public	Associate	Below 500	-	28
		500 - 2499	56	76
		2500 - 9999	537	194
		10000 - 19999	597	397
	Bachelor	Below 500	-	-
		500 - 2499	160	119
		2500 - 9999	105	344
	Masters	Below 500	-	79
		500 - 2499	131	257
		2500 - 9999	269	327
Private	Associate	Below 500	-	121
		500 - 2499	55	42
		2500 - 9999	-	207
	Bachelor	Below 500	12	24
		500 - 2499	51	72
		2500 - 9999	-	160
	Masters	Below 500	-	57
		500 - 2499	255	83
		2500 - 9999	202	244

are more than triple those for nonminority institutions in this same group and enrollment category.

The next largest difference occurs with public institutions offering associate degrees with enrollment above 2,500. Here the expenditures per minority institution double those per institution for other reporting institutions in the same group and enrollment category. Public minority institutions with enrollments of 2,500-9,999 and offering the bachelor's degree show about one-third the expenditures per institution as compared to the average for other institutions with similar status. Public minority institutions offering the master's degree and in the 500-2,499 range are spending about one-half that being spent by other institutions. The private minority four-year institutions with enrollments below 500 are spending approximately one-half as much per institution as the nonminority group in the same category.

Percentage Distribution of Staff

An analysis of data on staff, relative to FTE in the various staff positions, reveal that in 1976-77 about 17% of the staff members held management status; about 14% were clerical, 8-10% analysts, 5-6% system programmers, about 20% application programmers, and slightly more than 34% operators. These percentages were found to be approximately constant when comparing data from all minority, nonminority, and all Black institutions.

The percentage for American Indian, Spanish American, and "other" institutions showed marked deviations from the above percentages because of the small numbers of institutions and staff members in these groups.

The percent of computer-related expenditures for staff range from approximately 35-40% for the three groups given. It is clear from an examination of data on highest level of education of staff, involving all minority, nonminority, and Black institutions, that the corresponding percentages are approximately uniform. Here again the percentage of American Indian, Spanish American, and "other" groups are distorted because these are very small groups.

Computer Science and Related Degree Programs

Only two minority institutions offered the master's degree, sixteen offered the bachelor's, and seventeen offered the associate degree in computer science or related programs during 1976-77. None offered the doctorate. The total enrollment in the two master's programs was only fifty-eight students, all of whom were enrolled at two predominantly Black institutions. This does not imply that the enrollment in the two programs is predominantly Black. Since the largest of the master's programs was established less than six years ago, and many of the associate and bachelor's degree programs were also recently established, the academic computing experience of minority institutions is considerably less than that of the total university group.

Minority institutions, by introducing programs in computer science later than the other institutions, were able to pattern their programs after the others. This results in a great similarity. The course offerings were also influenced by the recommendations of the Association for Computing Machinery's Curricula Committee.

Comparatively, there is a need for additional programs in the minority institutions. Only 5.4% of the associate degree programs reported were in minority institutions. Approximately 4.8% of the bachelor's programs and 1.5% of the master's programs were at minority institutions. No minority institution offered the doctorate degree in a computer-related field.

Minority institutions reported an enrollment of 3,895 undergraduate majors in computer science and related programs. This represents 6.4% of the total for all institutions. The minority programs awarded 405 undergraduate degrees which represents 4.8% of the total.

As indicated by Table 7.4, there are some staffing difficulties. The minority institutions reported a total of thirty who held staff doctorates in computer science, or 0.42 computer science doctorates per program. Overall there were forty-one faculty and staff reported with doctorates or 1.32 doctorates per program.

The faculty and FTE staff was reported as 184 by all minor-

Table 7.4
Computer Science Program Faculty

Degree Area of Faculty	Number	% of Total
Doctorate in Computer Science	13	5.0
Other Doctorates	29	11.0
Other Part-time Staff	82	31.2
Teaching and Research Assistant	56	21.3
Other Staff (non-doctorate)	81	30.8

ity institutions. This included 123 full-time and 138 part-time (TAs, RAs and other) staff. Of these 21 held joint appointments with other departments.

Notes

1. Based on data from the U.S. Office of Education.
2. Fall 1975 enrollment data from the U.S. Office of Education.

8

Networks and Special Service Organizations

Charles Mosmann

Introduction

Quite early in the use of computers in support of education, it became evident that most campuses should have access to this novel resource but that only a few would be in a position to afford it. Although there was considerable agreement on the importance of computers in both research and instruction, the immense cost of these machines and--perhaps as important--the short supply of skilled technical personnel made their acquisition impractical for all but a few elite and research-oriented universities. In this context, the concept of sharing emerged: some smaller institutions might buy modest amounts of service from local large universities. Thus the first reason for sharing computing resources was their scarcity and their cost.

A second reason quickly emerged as a consequence of a growing awareness of the breadth of the computer's applicability. A computer in a business office or a government laboratory is intended to serve a small circle of users with a narrow range of interests. But a campus computer center soon attracts users from all over the institution with interests and needs across the

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entire spectrum of applications. Systems and applications software of every kind are germane to the interests of a university's faculty and students. Since no computer center could possibly claim to do everything for everybody, it was reasonable that even large universities might profitably share with one another.

Thus from the very beginning, two kinds of intercampus services were seen to be necessary: basic service to satisfy the needs of small institutions without the level of demand or the technical skills to acquire systems of their own; and more exotic systems to supplement the services available from any individual campus computer center. In situations of growing demand and declining costs, the first reason diminishes in importance; that is what happened in the late '60s and '70s. But the second reason continued and even grew in importance.

Furthermore, starting in the early '70s, a third impetus to sharing emerged. Alarmed by the proliferation of computers of all sorts and sizes and by the prospective costs of computerizing colleges and universities, those responsible for groups or systems of colleges considered the advantages of a coordinated approach. Cluster colleges, multicampus institutions, and statewide systems of education all became involved in this movement. The chief reasons put forth in these developments were economical: a large computer is cheaper than several small ones; several computers can be acquired and maintained more economically if they are of the same brand; software sharing is expedited by hardware sharing.

As natural as was the emergence of the sharing ideal, the approach carried with it a number of very serious problems, problems that defeated a depressing number of attempts at sharing. It is because of the inability of network managers and academic administrators to solve these problems that the "one-campus/one-computer" model remains the dominant mode of providing computing services in higher education.

The first problem in sharing an important resource between institutions is based in the traditional autonomy of colleges and universities. A campus that is responsible for registering its students, providing courses of instruction, and completing grant-funded research on schedule, must have some authority in managing the computing resources needed for these activities. The college cannot be at the mercy of some external agency that views collegiate goals as secondary. This was the major problem faced by the smaller institution buying service from a large university: the priorities of the user were bound to be secondary to those of the supplier.

The costs and inconveniences of transportation or communication also create a problem. When the distances are small (in cluster colleges for instance), cards and program listings can be carried by hand. Many early sharing efforts (and some that still exist today) relied on buses. Telephone communications and remote job entry stations were clearly more convenient; however, the amount of communication required to support the use of time-shared terminals and batch entry stations in a multicampus institution scattered across hundreds of miles is substantial. The quality required and the cost involved make the decentralization of at least part of the service almost a necessity.

More difficult than the transportation of data is the communication of expertise. Documentation of systems and software is frequently confused and inadequate, particularly to the novice. The freedom to take your problem to an expert and show him or her your output is lost when the expert is a hundred miles away.

Some institutions—particularly private colleges—find it easier to get funds for capital acquisitions than to spend operating money for services. Thus, there is no advantage to them to buy computing service when there is no computer to show a prospective donor.

Finally, the management skills needed to solve these problems are frequently unavailable to the educational institution. Some colleges and universities were forced to conclude that management talent was a scarcer resource than computers and that they were better off wasting some of the computer money than allowing computing issues to monopolize the time of the top level administrators.

Balancing these problems, however, are a few benefits that cannot be ignored. A shared service means greater service to the user at lower cost. It provides, in addition, the incidental benefits of cross-fertilization in research, instructional techniques, and administrative methods.

Historical Setting

The development of these principles, seen against the background of the dynamics of the computing industry and the changing face of higher education, is best shown in the context of a few specific developments: early shared resources, networks of different designs and levels of complexity, and specialized computer-based services.

In 1956, the Western Data Processing Center (WDPC) was established at the University of California, Los Angeles (UCLA) with the support of the IBM Corporation. The center was housed in the Graduate School of Business Administration. It was intended to provide computing services in support of research and instruction for colleges throughout the West, and at least five hours per day were guaranteed for this purpose. Users came from seventy-three different institutions. Although many of the campuses were close enough to UCLA that the users travelled to the center to do their computing, service was available by mail and from remote job entry (RJE) terminals as well. Although users with funded research projects were asked to pay for their computing, service to others was free.

WDPC served higher education for more than a decade before it closed down. It was never intended as a long-range solution to the problem of providing computing for higher education. It was designed to make computing available at institutions that had none or very little and to make them aware of this new resource and how it might be used in support of their programs. It was an early effort at interinstitutional cooperation but was abandoned in favor of the more convenient on-campus computer center when that approach became economically viable.

A second approach to resource sharing was EIN, the Educational Information Network. It was, in effect, an effort to establish a nationwide network without electronic communication. It was established in 1968 and existed for about three years. The heart of EIN was a catalog of available software. Prospective users could find a description of the program they wanted to run, prepare their data in accordance with the procedures specified, and ship their cards off to the computer center that had the program available. It was a sensible idea, certainly more convenient and economical than the prevailing practice of requesting a copy of the program and attempting to get it installed and running on your own machine. But it floundered on some of the problems listed above: the difficulty of documentation and the inconvenience and delay of shipping a job and waiting days or weeks for turnaround.

During the 1960s, the National Science Foundation (NSF) played a key role in supporting the creation and expansion of many academic computer centers. A study by the National Research Council of the National Academy of Sciences[1] forecast a need for more than $200 million for computers in education by 1968. The educational establishment was clearly incapable of raising this capital; the federal government would have to subsidize this development to a substantial degree.

Faced with the prospect of buying computers for colleges and universities by the hundreds, NSF turned to the sharing concept that had already been successfully explored by a few institutions. NSF would encourage the development of networks designed as single large centers, each serving several institutions. In the period from 1968 to 1972, NSF supported the development of twenty-five such centers and assisted in the expansion of others.[2] These were all general-purpose regional networks (that is, they provided a range of services to institutions within a limited geographical area) and were primarily of star design, one large computer at the center of the network with users connected to it but not to one another. The users might have computers with limited capabilities or simple RJE stations connected to the center.

Some of these twenty-five centers succeeded and still exist. Many of them, however, prospered only while the NSF funding lasted. When the member institutions had to bear the full cost of the services themselves, they turned to other approaches, usually buying an on-campus computer. The management problems described above again proved too intractable for the network administrations involved. When the central computer of the network was on the campus of one of the members—and it was likely to be the largest, richest, and most prestigious of them—the other members were likely to see their position as second-class. They felt that they obtained only the service left over after the needs of the large university were satisfied.

Two notable exceptions to this phenomenon deserve explicit mention—the Triangle Universities Computer Center in North Carolina (TUCC) and Dartmouth. Neither was established with NSF support, although both received NSF help to expand along the way.

TUCC was established as a private corporation owned jointly by the University of North Carolina, North Carolina State University, and Duke University. It was established on neutral ground in a "research park" approximately equidistant from the three campuses; it began operations in 1965. Each of the three members bore one-third of the cost and received one-third of the service. Each of the members has some on-campus computational capability as well and supplies its own user services. Thus, TUCC can be seen as a producer of wholesale computation, which is packaged and marketed by the on-campus user service agencies.

Since its initial design, the only major change has been the addition of a customer, which now purchases a significant portion of TUCC's services: North Carolina Educational Computing Services. NCECS retails the services it purchases to many smaller colleges and universities throughout the state.

The reasons for TUCC's longevity are not hard to see: careful management of priorities, so that none of the members is seen as second-class. The wholesale/retail distinction helps in this regard, as does the use of some "leveling" parameters in the priority algorithm. The wholesale/retail distinction also helps solve the problem of distance: the primary user services personnel, the people with whom users want to talk when they have problems, are not at TUCC; they are on the campuses.

The situation at Dartmouth is strikingly different. The Dartmouth center was a pioneer in the use of time-sharing and developed an excellent service for on-campus use. The high quality and innovative design of the system made it attractive to other colleges (and high schools) which were permitted to buy service. Because the service was interactive to terminals, a simple telephone line and a rented teletype were the only investment the buyer had to make. No commitment for future use was required. Dartmouth had excellent documentation and provided good service. Although the customer was clearly second-class (since the primary function of the system remained the satisfacton of on-campus needs), second-class service was in many cases far superior to what the customer might have obtained by any other means.

Distributed Networks

Of the systems for sharing described so far, only EIN, the nonelectronic network, functioned without a single large computer at the center of the design. Other efforts were made to facilitate the exchange of service among institutions without a "center" to the network. One early effort at such a distributed network was NERComP (New England Regional Computing Program) which assisted forty to fifty institutions to make use of the services of six providers of service including Dartmouth. NERComP leased telephone lines, established documentation standards, and otherwise facilitated the exchange of service. It is interesting to note that NERComP had as its direct antecedent the New England Regional Computer Center (NERCC), which was the eastern analog of WDPC, the western center at UCLA described earlier. When NERCC closed its doors in 1967, the principal users formed NERComP, with the help of NSF funding.

In the interests of furthering research, the Advanced Research Products Agency (ARPA) of the Department of Defense began the design of a national distributed network in 1966. It was implemented by 1969 with four nodes; in its complete form it has more than forty. The network is a means for transferring information back and forth between large computers; it is designed to give the researcher access, through his own campus computer center, to all of the major research computers in the United States and even beyond. The key to the system is the Interface Message Processor (or IMP), a special purpose computer that interfaces the member's computer to the network. To join the network, an institution must buy an IMP (about $45,000), make changes to its own hardware and software that are needed to allow use of the IMP and the network, and pay the necessary maintenance and communications costs.

It is thus clearly a system to attract members from large rather than small institutions. ARPAs users are those researchers who need access to hardware or software available at only a few centers and whose work is important enough to justify the cost of providing network access to those centers.

EDUCOM–the Interuniversity Communications Council–is a consortium of colleges and universities with a strong interest in computer networks. It formulated, as early as 1966,[3] a proposal for a nationwide, multimedia network to be called EDUNET. EIN, described earlier, was actually projected as the first phase of EDUNET. The actual implementation of an electronic network had to wait for the solution of many problems: technical, financial, and the continuing problem of the provision of user services. A major study published in 1974[4] attempted to structure the problems and prepare a means of solution.

Largely as a result of this impetus, a network "Planning Council" was created with a small membership of universities, to conduct experiments and simulations to decide on the viability of the long-envisioned EDUNET and, if viable, its most appropriate design and structure.

EDUNET came into being in 1978 as a national computer resource-sharing network for higher education. Its underlying philosophy is to facilitate the sharing of specialized computing resources made available by the EDUNET suppliers (currently about fifteen major computer centers) to the entire academic community. Unlike ARPA, there are two kinds of members: suppliers, who must take the initiative of providing the hardware, software, and documentation to make their services available on the network and useful to a wide range of potential users; and users, who must make a much smaller commitment. As with ARPA and NERComP, EDUNET is a facilitating and managing organization and is not directly involved in the provision of services. The success of the network rests on the premise, long voiced but never fully tested, that colleges and universities are willing to buy services from other institutions as a cost-effective alternative to producing services themselves and that they will do it in a volume sufficient to support the overhead of the network itself.

State and Regional Networks

As indicated earlier, a great share of the impetus to cooperation in academic computing comes from coordinating boards, state departments of higher education, and system-wide offices. The requirement to provide resources for several campuses made such agencies consider the innate economies of an organized and systematic approach to campus computing.

In the early 1970s, more than half of the American states and Canadian provinces were involved to some degree in feasibility studies or the actual development and use of cooperative systems for educational computing. The issues were complex and the problems were difficult, involving a curious mix of technology, educational principles, and politics. A single case will serve as an example, after which more general observations about these networks will be made.

One of the earliest and most successful of the statewide computing systems is that of the California State University and College system. This institution has nineteen campuses, varying widely in size and dispersed throughout this large state. The central agency (Chancellor's Office) exerts a considerable degree of control over the plans and policies of the campuses; the state Department of Finance exerts its financial influence as well. Thus when networks began to be discussed, it was reasonable to hope that a system could be designed and imposed on the state university system even if there was not universal enthusiasm for the concept on the campuses.

The system became operational in 1969. Each campus had a small computer which was intended to process the bulk of the instructional load and some of the smaller administrative jobs. The more demanding jobs were forwarded to two regional centers—one in the north of the state and one in the south. A further level of service was available: jobs demanding special services not available within the system could be forwarded to the large computer center at UCLA (part of the University of California, a different system).

Since its inception, the two regional centers (which were on two of the campuses) have been replaced by a single center (attached to the Chancellor's Office). The only other major change was a consequence of the decision to expand significantly the availability of interactive computing for purposes of instruction. Some interactive service had been available from a centralized site; however, the provision of interactive service to support instruction at nineteen institutions with more than a quarter million students requires either mammoth communications systems or further decentralization. The decision was made to provide each campus with its own minicomputer (independent of the batch system which comprises the network) to support interactive student use. The nineteen computers were acquired through a single purchase and are thus compatible for the development and maintenance of software. In addition, a centralized interactive system is also available for jobs beyond the capabilities of the on-campus systems.

The prospective computer user on one of the campuses thus has four systems to choose from: local batch, system-wide batch, local time-sharing, interactive time-sharing. It may be worth noting, finally, that plans are under way to replace the batch computers (both the local and central systems). Although the design is not final, it seems likely that the systems will be totally compatible (i.e., twenty computers from the same vendor), that more interactive service will be available, and, most significantly, that more of the computing power will be on the campuses and less in the center. Thus the design of the system as a whole has been moving from a star network with some decentralization toward a structure of parallel but independent systems.

Two studies[5,6] have been made of the development of statewide networks, the reasons for their emergence, the causes of the failures and the successes. The interested reader is referred to them for more details in this history.

A few principles emerge from these two analyses, some of which can be cited briefly. First, the bureaucratic structure and nature of control are significant: purely voluntary cooperation is not likely to be sufficient to create a stable sharing situation. Second, a homogeneous group of institutions is more likely to create a harmonious system than one with members divergent in interests, size, goals, and political power. Third, a successful network is only possible if a cooperative attitude toward sharing exists and if the members feel a commitment to making the effort succeed; this may take effort and time to create.

Special Service Organizations

Another type of network or sharing of service exists: organizations that provide only a narrow range of services to a particular clientele. Some offer computing services on a system configured (in terms of both hardware and software) to solve the kind of computational problems encountered in a particular discipline. Others offer particular services (e.g., literature search) that are provided by means of computers. A few of each type will be discussed.

Discipline-oriented Services

The National Center for Atmospheric Research in Boulder, Colorado, provides a large facility with some special purpose software exclusively for the use of researchers in meteorology and allied disciplines. The Lawrence Berkeley Laboratory is a center configured to serve the needs of research in atomic energy and provides its services, at heavily discounted rates, for relevant federally sponsored research projects. These centers and others like them are available to users in several ways: some users travel to the center to conduct their research, others make use of RJE terminals connected by telephone, others use them via an existing network such as ARPA or TELENET (a commercial network based on the ARPA network technology). Brookhaven National Laboratory and the Illiac IV at NASA Ames are similar centers, available to researchers on a national basis.

In some disciplines, particularly chemistry and energy research, several centers with computing resources of interest have been connected via such general purpose networks to create "subnets" of considerable power. The Energy Research Development Administration (ERDA) community is such a group. ERDA supports the activities of some twenty laboratories and research centers, as well as projects at over one hundred universities and private organizations. The nature of the work sponsored by ERDA requires the development and use of complex computer-based models, analytic programs, and data bases. The work is naturally distributed across the country and it is not possible to provide the complete range of these necessary services at every site. A "distributed network" has therefore been established, using both the ARPA network and TELENET to make the services available to each of the research centers. This enables the sharing of unique hardware, software, and data bases; it has also contributed to the development of some research collaborations.

Within this distributed network, other net-like structures can be seen to emerge. The Magnetic Fusion Energy network, for example, is a star network within the ERDA network: it has one host computer and several strategically located user service centers.

The ARPA network is a physical network, consisting of computers, communications links, and so on. The ERDA network and its subnets are logical or intellectual networks that make use of the basis provided by a physical network. Some logical networks actually transcend the boundaries of a physical network. Austin[7] describes the concept of a network gateway, "a host having access to two or more networks, and which supplies the necessary protocol translation software to allow messages to flow from one network into another." Thus within a discipline or community of users of common interest, networks of enormous power can be constructed.

Instruction-oriented Services

A special word should be said about network resources for instruction. PLATO is undoubtedly the best known. The PLATO project included the development of a high capability display terminal specifically for use in instruction and the simultaneous development of TUTOR, a special-purpose programming language, and lesson materials. PLATO was developed at the University of Illinois, with support from the State of Illinois as well as NSF. The system is now operational and is widely used. Communication is by means of leased telephone lines. The entire system (computer plus software plus lesson materials) has been replicated in two other locations: in Minneapolis (operated by Control Data Corporation) and in Tallahassee (operated by Florida State University). Each has the outward appearance of a general-purpose time-sharing system but serves a much more limited function—interactive, computer-aided instruction.

CONDUIT is a "soft" network—that is, it involves the sharing of software but not hardware. Its efforts have been concentrated in the area of improving standardization of languages and establishment of documentation standards to enable computer-based instructional materials to move from campus to campus.

In 1972, the National Library of Medicine established an experimental computer-assisted instruction (CAI) network; this has developed into the Health Education Network.[8] Network hosts are the Massachusetts General Hospital and the Ohio State University College of Medicine. The instructional materials at Massachusetts include about thirty simulations, with an emphasis on the process of clinical problem solving. The Ohio library contains more than 350 hours of interactive instructional material. Over 150 institutions in forty states are users of the Health Education Network. Other instructional materials are being developed on a similar model. Most notably, a series of instructional programs in law has been developed and is now in use by a number of institutions across the nation via EDUNET.

Information and Bibliographic Services

A large number of agencies disseminate bibliographic information on a general or specialized basis. Many of these systems are on-line, allowing the user immediate feedback in response to a request. ERIC, COMPENDEX, and MEDLINE are large bibliographic data bases used this way; access is by means of query systems provided by various commercial vendors as well as universities and public agencies such as the National Library of Medicine.

A significant difference exists between these services and those described earlier. These are likely to be viewed by the ultimate user as *information* services rather than *computing* services. The user goes to the library rather than the computer center to acquire them; he or she probably describes the information required or fills in a form and does not see or touch a computer terminal. It is thus a highly buffered computing service, designed to look to the user like a traditional library reference service.

The Chemical Abstract Service (CAS) of the American

Chemical Society is one of the oldest and most comprehensive computer-based abstracting and indexing systems in existence. CAS adds about 1,500 abstracts a day to its data base, from as many as 14,000 primary journals. From this data base, information is extracted and sent (via magnetic tape) to CAS information centers as well as to end users.

The MEDLINE service at the National Library of Medicine provides single point access to its data base through a time-shared network. The user has access to nearly two million citations. In 1972, usage was at the rate of more than 10,000 searches a month with service being provided to about 130 institutions.

The *New York Times* Information Bank provides, on a subscription basis, access to a very large data base, consisting essentially of abstracts of *Times* articles from 1970 to present, with selected abstracts from other sources. Customers include many large libraries, which make the service available to their clients.

Service of a slightly different kind is provided by the several agencies providing technical support to libraries. The best known are RLIN (formerly BALLOTS from Stanford University for the Research Libraries Group) and OCLC, the Ohio College Library Center. OCLC provides an on-line acquisition and cataloging system, using the Library of Congress MARC tapes as the primary data base. As institutions use it, the OCLC system builds up a greater data base and effectively creates an on-line union catalog as well. It was developed for use by Ohio college libraries but now it is used on a national basis.

All of these services are offered to libraries to aid them, directly or indirectly, in serving the needs of their clients for bibliographic and other information. They complete a spectrum of networks that includes access to large, powerful machines, specialized hardware and software, computer-based services such as CAI, and background systems of which the user may be only dimly aware.

Trends in Network Use

When we turn to the data collected in the FICHE inventory of 1976-77, there are five significant questions to which we might hope to find answers:

1. What is the volume of network use?
2. Is the trend increasing or decreasing?
3. What kinds of institutions are likely to be users of off-campus services?
4. What kinds of institutions are likely to be suppliers of such services?
5. What kinds of services are being transferred?

The data are not so indicative as to provide final answers to these questions, but they can shed at least some light on all of them.

What Is the Volume of Network Use?

On Form 1 of the survey instrument, respondents were asked to identify off-campus use in terms of three categories: cooperative/nonprofit vendors, other colleges or universities, commercial. Each installation was asked the cost of service acquired in each category. On Form 2 respondents were asked whether use was made of off-campus service (in each of the same three categories) and the name of the agency from which the service was purchased. The responses from the two forms differ significantly, since Form 2 did not include administrative uses, and installations which did not keep usage records did not respond to Form 2.

Installations using off-campus service for which no billings are made (e.g., within a multicampus institution) may not be reflected in the first set of answers; administrative uses may be excluded from the second set. Off-campus use which is made directly from the user to the off-campus agency without going through an on-campus computer installation (e.g., library use of a bibliographic service) may also be excluded.

The percentages of positive responses on the three questions on the forms (for all responding institutions) are as shown below:

	Form 1	*Form 2*
Cooperative/nonprofit	2.9	6.6
Other college/university	6.2	13.8
Commercial	3.4	2.6

I shall use the data from Form 1 on commercial use, since this is more likely to include administrative services.

As the data presented in the table above indicate, the use of off-campus services by colleges is by no means rare or unusual. Such use is most likely to be from other campuses; less likely is its acquisition from a cooperative or nonprofit agency; least likely is the use of a commercial vendor of services.

The percentage of institutions reporting the use of such service is high; the actual dollar cost reported is surprisingly low: $10.5 million, only 2.0% of the combined computer budgets reported.

Ninety-nine installations report spending money at other colleges or universities; the average total expenditure per installation was $44,000. Twenty-one installations report receiving money from other colleges and universities; the average income from this source was $245,000.

Thus we may conclude that the volume of cooperative computing is very small in terms of absolutes: less than 2% of the computing used comes from off-campus sources. However, approximately 25% of the campuses use computing services from other schools or vendors.

Another question asked each installation to identify its network status. The results are as follows:

	Number of Responses	*Percent*
Network only	68	5.7
Network and local	305	25.6
Local only	818	68.7

Thus we note that nearly one-third of the installations responding to Form 2 have some network capability.

Is the Trend Increasing or Decreasing?

Questions about the volume of use of off-campus sources were also asked in the 1969-70 survey. Comparisons of the responses in the two surveys are as follows:

	1969-70	*1976-77*
Cooperative/nonprofit	6.0%	6.6%
Other college/university	18.4%	13.8%
Commercial	13.2%	3.9%
Average dollars per installation spent off-campus	$13,600	$91,700
Percent of expenditures off-campus	1.5%	2.0%

It is clear from this comparison that the rate of involvement in network computing has gone down slightly—a smaller percentage of the institutions are involved except for the cooperative/nonprofit agencies. But the dollar value of the services transferred has nearly tripled and one-third higher percent of the total budget is involved.

We should also take note of the differences between the three sources: a slightly greater use of cooperative or nonprofit agencies; somewhat less involvement of intercampus sharing; and a considerable reduction in the use of commercial service. We will return to this point later.

What Kinds of Institutions Are Likely To Be Users of Off-Campus Services?

As noted above, colleges report relatively heavy use of networks to access computing facilities at other colleges and universities (13.8%). In terms of size, the heaviest response was from medium-sized institutions (2,500-9,999 enrollment), with 16.9% positive response. The closest other group was the 500-2,499 enrollment category with 15.6% using other college/university services. Master's level institutions are more likely to use such services (20.1%) than other levels, and public institutions are more likely to do so than private ones.

The pattern of use of cooperative or nonprofit agencies is not dissimilar, although more large institutions (10,000-19,999) are involved, and there is no difference between the percentage of involvement of public and of private institutions.

The use of commercial service is heavily concentrated in the smaller colleges, at the bachelor's level, and in the private sector.

An analysis of the dollar volume indicates a close parallel with the percentages of institutions—heaviest at medium-sized institutions at the bachelor's and master's levels.

What Kinds of Institutions are Likely To Be Suppliers of Such Services?

It is not surprising that large institutions, and those at the doctoral level, are more likely to receive income from the sale of off-campus services than any other type of institution. Of the twenty-one institutions declaring such income, eleven are doctoral level with enrollments of 10,000 or more; of these eleven, nine are public institutions.

If we examine the specific agencies cited by the users as the sources of service, some further trends are evident. Among cooperative or nonprofit agencies, we find many statewide agencies, system and district offices, and some governmental or other noneducational bureaus. Only a few national services are mentioned: RLIN, OCLC, NERComP, NCAR, ARPA. Specific college or university sources are, as one might expect, heavily oriented to the large universities.

The commercial agencies cover a bewildering gamut. However, banks and service bureaus seem to comprise the bulk of those listed. Considering that the users tend to be the smaller private colleges, the surmise that administrative data processing services are being acquired seems reasonable.

What Kinds of Services Are Being Transferred?

The data provide no clear indication on this question, of course. But, from noting the kinds of institutions acquiring services and the names of the organizations from which they are acquired, some hypotheses can be made. These are not inconsistent with what one might conclude from the earlier analysis of the history and current status of networks. The following generalizations might reasonably be made:

- Some small institutions buy general-purpose computing from larger institutions.

- Very small private colleges are likely to buy administrative data processing services from banks or service bureaus.
- Medium and large institutions may get computing from a nonprofit or cooperative center.
- Use of special service organizations has not been reported to the volume that appears likely.

The last point deserves some explanation. Many agencies that report heavy use from a large number of campuses (e.g., Chemical Abstracts, ERDA centers, PLATO) are not mentioned in any of the responses. I would argue that their absence from this survey is due to the position and interests of the respondents and the emphases on general-purpose computing. If librarians and chemists and other faculty members, rather than computer center personnel, had responded, much more usage of this type might have been reported.

Present and Future Impact

In attempting to assess the present importance of intercampus sharing of resources, we are faced with conflicting indicators. Networks report their dynamic growth and good health, but institutions report a disappointingly small volume of use. Users are enthusiastic in acclaiming the importance of off-campus use, and computer center directors fear the demise of their organizations; but fewer than one-third of the institutions reporting show any use of networks at all, and reported expenditures for such are less than 2% of the total. Does networking exist in any important sense at all or are we faced with another case of the "emperor's new clothes"?

One must admit that many of the promises made on behalf of networks over the past decade have been excessive, based on the enthusiasm for a new idea and on the admitted potential of the new technique. Networks will never supply the bulk of computing to colleges and universities, or even a large share of it. Large off-campus computers have too many disadvantages to compete effectively with smaller machines for processing student jobs in BASIC or FORTRAN, in performing routine statistical analyses, or any of the work that makes up the bulk of campus use.

The idea of an integrated national network (or overlapping set of networks) of shared computing resources persists, however, because there is more to computing than this straightforward job mix. Although 90% and more of the computing that is requested can be performed by machines on-campus, the remaining few percent cannot be ignored. The networks allow computer centers to provide a full range of services for everyone. The user today (and, one hopes, to an even greater extent the user of the future) has a hierarchy of options. The researcher, the instructor, and the institution that houses them will follow their self-interests in shopping for the best (and in some cases the cheapest) service to satisfy the specific requirements of the job.

Network use is, and will likely remain, a small part of the academic computing scene. If all computing absorbs 3% to 4% of academic budgets and 2% or less of this goes into off-campus computing, then off-campus computing is not a matter of much interest from a budgetary point of view. However, if we think of networking as a means of transferring intellectual products and resources from campus to campus rather than as an alternative source of computing, it has a value far in excess of the modest cost represented by these statistics.

Notes

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4. M. Greenberger, J. Aronofsky, W. McKenny, and W. Massy, *Networks for Research and Education: Sharing Computer and Information Resources Nationwide* (Cambridge: MIT Press, 1974).

5. C. Mosmann, *Statewide Computing Systems: Coordinating Academic Computer Planning* (New York: Marcel Dekker, 1974).

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9

Computer Science-Related Degree Programs at the Associate Level

Joyce Currie Little

Introduction

The development of computer science-related associate degree level programs and courses began in the late 1950s. Early programs in business related data processing were modified to include computer-based data processing concepts as they became available. People with industry experience worked with, and in, junior colleges to develop courses such as "Introduction to Data Processing" even before the creation of the associate level programs.

With the support of the U.S. government, matching federal dollars became available to rent or purchase equipment, such as the IBM 1620 and 1401. Large discounts by certain manufacturers to educational institutions permitted colleges to obtain equipment for the initiation of programs; early courses in programming were offered on this equipment. In courses that utilized electro-mechanical accounting machines (EAM) or tabulating equipment, students formatted the printing of reports. In programming courses the machine language, assembler language and FORTRAN were taught.

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In 1963, the U.S. Department of Health, Education, and Welfare released curriculum guidelines for curricula in business data processing, covering a wide range of careers. In 1964, another report was released, for programs in data processing in engineering, science, and business. These two government documents were instrumental in the initiation of programs in the 1960s, and a rather explosive growth in courses at the associate level followed.

Early courses at the associate level were under the administration of business related departments and were generally named "business data processing." As the language COBOL was developed and made available, associate level programs began to phase out emphasis on EAM or unit-record equipment, assembler languages, and FORTRAN, in order to stress COBOL. Two-year colleges often acquired a central computer facility with the help of the faculty in the business data processing area, and instructional programs began to share equipment with a computer services department rather than have exclusive use of it. As unit-record equipment usage declined in favor of more computer-based processing, programming emphasis increased and EAM equipment decreased. Departments of data processing arose out of the business departments.

In the early 1960s mathematics departments at the associate level gained interest in computers, time-sharing services became available, and associate level scientific data processing programs and mathematics-related computer courses grew. In 1970, the U.S. Department of Health, Education, and Welfare released guidelines for curricula in scientific data processing technology. Thereafter, associate-level courses in scientific applications in mathematics departments became more like the computer science programs in existence at the baccalaureate and graduate levels. Often associate-level faculty patterned their courses on baccalaureate programs that were based on ACM's Curriculum '68 guidelines for programs in computer science.[1] The associate degree programs were further strengthened by delegation to the community colleges of the task of educating computer programmers made in the Curriculum '68 and the 1973 ACM report for undergraduate programs in information systems.[2]

In 1973, the 1963 U.S. Department of Health, Education, and Welfare guidelines were revised, producing a report entitled *Data Processing Technology.*[3] In 1975, an ACN community and junior college curriculum group began to work on recommendations and guidelines to strengthen the associate level programs in computer programming. All of these events led to more attention, but not necessarily more coherence, for associate-level courses and degree programs in computer science.

Trends Evident, 1966-76

Inventories done in 1966-67 and 1969-70 showed a sharp increase in the number of associate degree programs, with an estimated 178 programs in 1966 more than doubling to an estimated 405 in 1969. By 1972, the number had climbed to 445. Before the 1974 survey, however, the number of programs declined, with approximately 338 that year. Growth began once more, reaching an estimated 568 programs in 1976, and surpassing its earlier maximum. See Table 9.1 and Figure 9.1 for a summary of these trends.

Previous surveys reported an average of 7 graduates per associate degree program in 1967, producing an estimated 1,290 graduates. By 1970, almost 15 per program were being produced, for an estimated 6,051 graduates. As shown in Table 9.1, graduates reached an average of 15 to 18 per year per program in the late 1970s, or approximately 8,211 graduates in 1977 and 10,170 in 1978.

Data processing was the most prevalent degree program reported in 1966-67 among the 142 programs at the associate level: 122 were data processing programs and 7 were computer science. At that same time, only 72 baccalaureate programs were reported, of which 30 were computer science and 11 were data processing. Not only were there only about half as many baccalaureate programs; those that did exist were not the same types of program.

The 1966-67 survey showed 86% of reported associate level programs using the name data processing, 6% using the name computer technology, 5% using computer science, and 3% using computer programming. During the drop in the number of programs in the early 1970s, the proportion named data process-

Table 9.1
Number of Associate Level Programs and Graduates Reported and Estimated 1966 to 1979

Survey Year	Reported Number of Programs	Est. Ratio	Estimated Number of Programs	Reported Number of Graduates	Estimated Number of Graduates	Ave. No. Grads/PGM
1966-1967	142	1.25	178	1032	1290	7.3
1967-1968	-	-	-	-		
1968-1969	-	-	-	-		
1969-1970	302	1.34	405	4516	6051	14.9
1970-1971	323	1.34	433	5614	7522	17.4
1971-1972	332	1.34	445			
1972-1973	-	-	-			
1973-1974	206	1.64	338			
1974-1975	218	1.64	357	3915	6421	18.0
1975-1976	230	1.64	377			
1976-1977	330	1.72	568	4774	8211	14.5
1977-1978	335	1.72	576	5913	10170	17.7
1978-1979	335	1.72	576			

ing changed from 86% in 1967, to 68% in 1971, 58% in 1974, and 55% in 1978, while those named computer science increased from 5% in 1967, to 12% in 1971, 17% in 1974, and 19% in 1978. Figure 9.2 illustrates these changing proportions. By 1978, only 4% were named computer technology or computer science technology.

The number of baccalaureate programs doubled by 1969-70, while the associate level programs more than doubled. However, the growth was predominantly in the computer science type of programs at the baccalaureate level, and in the data processing programs at the associate level. By 1975, the number of reported programs at the baccalaureate and associate levels were equal. By the 1976-77 survey, the number of baccalaureate programs surpassed the number of associate level programs, but the inver-

Figure 9.1
Estimated and Reported Number of Associate Level Computer Science-Related Programs

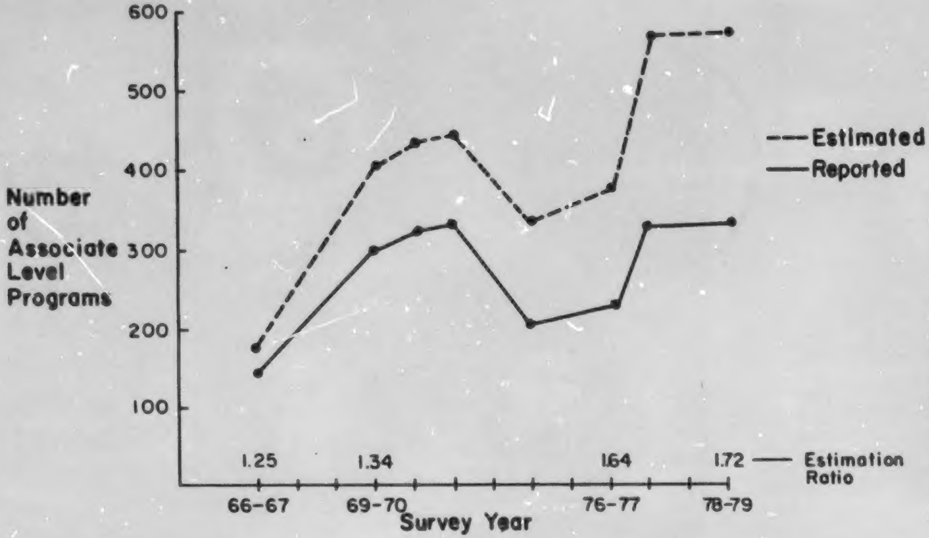
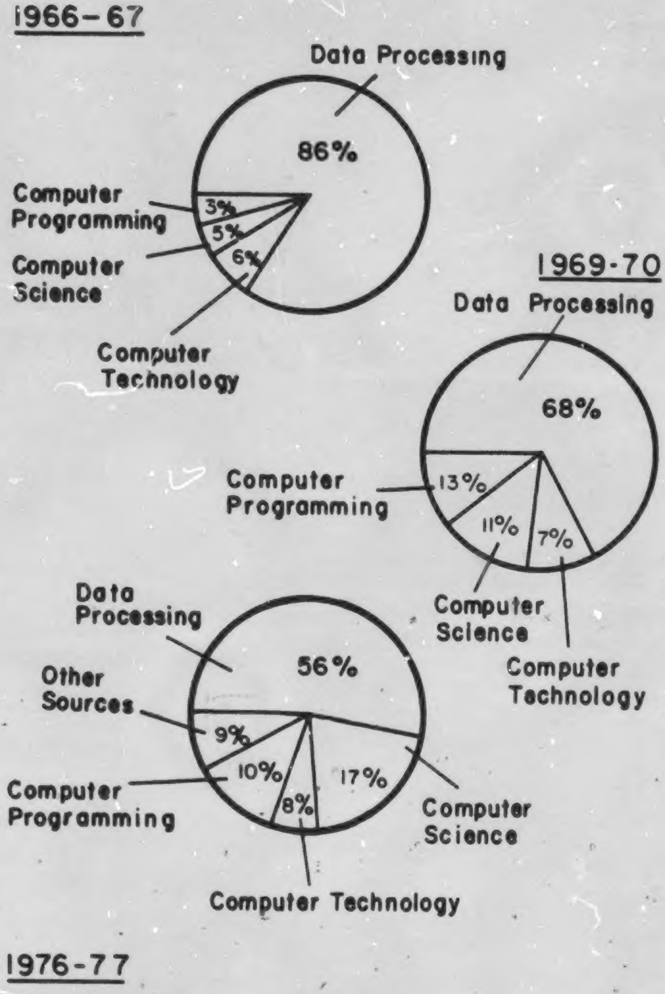


Figure 9.2
Proportion of Reported Associate Degree Programs by Name



sion of the porportion of types of courses within each level had not changed: most of the associate level programs were data processing and most of the baccalaureate were computer science. More detail on baccalaureate programs is presented in the next chapter.

At the associate level, the number of computer science programs is increasing, data processing and computer technology are decreasing, and the number of computer programming programs remain steady. Courses in information systems are beginning to appear. These changes may indicate the creation of new programs, or name changes being made to reflect an upgrading of data processing programs to include more computer-oriented content.

Because of an almost inverted proportion, with most associate level programs in data processing emphasizing COBOL and business applications work, and with baccalaureate level programs emphasizing FORTRAN, scientific applications, and computer science, difficulties arose in "articulation" between the two levels. As baccalaureate programs in data processing and information systems begin to grow, and computer science and scientific applications programs increase at the associate level, transfer of students from associate to baccalaureate programs should become easier.

Host Institution

The 1976-77 survey showed 331 reported associate programs based upon a 58% response rate. In 1977-78, there were an estimated 576 associate level programs nationwide. Of the 331 reported programs, 250 are taught in associate level institutions, 32 in baccalaureate level institutions, 40 in master's level institutions, and 9 in doctorate level institutions. Table 9.2 shows the reported number of programs, by selected program name and by level, from the 1976-77 survey data. In all programs except one, the largest proportion of associate degree programs is housed in a two-year college: the one reported associate degree program in computer engineering is housed in a master's level college.

Table 9.2
Reported Number of Associate Level Programs by Selected Program Name for Level of Institution 1976-1977

Program Name	Associate	Baccalaureate	Masters	Doctorate
Computer Engineering	0		8	
Computer Programming	568	11	12	0
Computer Science	486	85	75	1
Computer Science & Engineering	5	-	0	0
Computer Science Technology	47	33	0	5
Computer Technology	87	0	41	21
Data Processing	2859	40	62	97
Information Systems	65	2	6	3
Others	120	37	9	0
Totals	4237	208	213	127
# Grads/Program	16.9	6.5	5.3	14.1

Number Reporting - 331

Type of Program

Computer engineering, or computer science and engineering, and sometimes computer technology associate level programs tend to be oriented towards electronics and hardware. Associate level programs in data processing and information systems tend to be business-oriented applications computer programming, and computer science associate degree programs tend to stress mathematically (or scientifically) oriented computer applications or preparation for transfer to baccalaureate programs in computer science.

Most (179) of the 331 programs reported in the 1976-77 inventory were data processing degree programs. The next most popular degree programs were computer science and computer programming (36). Associate level programs offered in associate level institutions tend to be named data processing. Most offered within baccalaureate and master's level institutions are computer science, but associate programs offered within doctorate level institutions are mixed. Refer to Table 9.2 for details.

Public versus Private Institutions

Most existing degree programs in the associate level institutions are housed in public institutions with enrollments between 2,500 and 9,999 students. Private institutions reported only 7 programs in the 1976-77 survey of the total 250 programs in associate level institutions. Over all levels of institutions, however, private institutions offer 40 associate level programs, while public ones offer 290. Institutions with enrollment below 500 offer only 2 programs in public and 4 programs in private ones. Institutions over 20,000 in enrollment reported only 17 programs in the survey, all in public institutions. Programs at the associate level are most prevalent in institutions with enrollments greater than 500 students and less than 10,000 students, as shown on Table 9.3.

Host Department

In 1976-77, most institutions reported data processing pro-

Table 9.3
Number of Associate Programs Offered in all Level Institutions Public vs. Private, by Size 1976–77

Enrollment	Support	Data Processing	Computer Science	Computer Programming	Others	Total
< 500	Public	0	1	1	0	2
	Private	2	1	1	0	4
< 2,500	Public	52	15	10	16	93
	Private	3	11	4	5	23
< 10,000	Public	85	22	18	18	143
	Private	3	6	0	3	12
< 20,000	Public	24	6	1	4	35
	Private	0	1	0	0	1
> 20,000	Public	10	0	1	6	17
	Private	0	0	0	0	0

grams (158 of 331), and most of these are in a Department of Data Processing (110 of 158). Other data processing programs are within the Department of Business Administration or Department of Business. Computer programming degree programs are distributed in a variety of departments, and computer science degree programs are located primarily in the Department of Computer Science (31). Other scientific computing courses are taught in the Department of Mathematics. In institutions where both computer science and data processing needs have been met in one department, the name is some combination of the two. In institutions where these two majors have not been combined, departments sometimes exist separately and compete for students.

Enrollment by Courses: Associate Level

Analysis of associate level course offerings for 1976-77 survey data is presented only for associate level programs offered in associate level institutions. Enrollments in other associate level programs in higher level institutions is combined with those of baccalaureate and higher level enrollments. Table 9.4 presents data on course enrollments for selected courses for 1969-70 and 1976-77, with a change index calculated from the change in numbers of students enrolled per program. Estimating enrollments for institutions that did not respond to the 1976-77 inventory, one increases the total enrollment in each course but not the average figure per course. Thus the average enrollment per course is the best indicator of the extent of instruction. Table 9.5 presents estimated course enrollments for 1969-70 and 1976-77.

Introduction to Data Processing. The most popular and prevalent computer course in the programs offered by associate level institutions is "Introduction to Data Processing." This course is generally required of all majors, and is taken by business students as well as others. In the 1969-70 study, 47,108 students in 302 programs were reported enrolled in this course, approximately 156 per program. In the 1976-77 study, enrollment in this course had increased to about 219 per program in

Table 9.4
Reported Course Enrollments at Associate Level Institutions With Growth Index 1969–70, 1976–77

Course Name	1969-1970 Reported Number Enrolled	1969 Index	1976-1977 Number Enrolled	1976 Index	Index Change
Basic, Fortran Type Programming	25,287	83	32,391	130	47
Cobol Type Programming	16,137	53	21,686	87	34
Intro. to Programming	16,002	53	13,581	54	1
Programming Languages	2,128	7	3,656	15	8
Introduction to Data Processing	47,108	156	54,710	219	63
Data Preparation	3,615	12	5,360	21	9
Systems Analysis, Introductory	5,534	18	5,554	22	4
Systems Design, Intro. & Adv.	3,195	11	2,912	12	-1
Business Applications	4,102	14	4,094	16	2
Scientific Applications	2,364	8	2,744	11	3
Data Communications	344	1	1,045	4	3
Operating Systems	4,040	13	5,194	21	8
Computer Center Management	688	2	857	3	1
Computer Appreciation	6,350	21	9,303	37	16
Data Structures	480	2	457	2	0
Discrete Structures	80	0	120	1	1
Artificial Intelligence	8	0	0	0	0
Hybrid Computers	10	0	14	0	0
Switching Theory	0	0	182	1	1
Compiler Construction	169	1	189	1	0
Computer Organization, Intro.	872	3	1,819	7	4
Computer Organization, Advanced	70	0	255	1	1
Simulation	13	0	0	0	0
Graphics	71	0	130	1	1
Process Control	212	1	181	1	0
Numerical Analysis	1,645	5	750	3	-2
Data Base Management Systems	92	0	364	1	1
Management Information Systems	589	2	376	2	0
File Organization	192	1	371	1	0
Advanced Course in Data Processing	2,148	7	2,211	9	2
Electric Accounting Machines (EAM)	12,165	40	1,043	4	-36

Number Reporting 1969-70 = 302

Number Reporting 1976-77 = 250

Table 9.5
Estimated Course Enrollments at Associate Level Institutions 1969–70, 1976–77

Course Name	1969-1970 Estimated Number Enrolled	1976-1977 Estimated Number Enrolled
BASIC, FORTRAN Type Programming	45,976	58,893
COBOL Type Programming	29,340	39,429
Intro. to Programming	29,095	24,693
Programming Languages	3,869	6,647
Introduction to Data Processing	85,651	99,473
Data Preparation	6,573	9,745
Systems Analysis, Introductory	10,062	10,098
Systems Design, Intro. & Adv.	5,809	5,295
Business Applications	7,458	7,444
Scientific Applications	4,298	4,989
Data Communications	625	1,900
Operating Systems	7,345	9,444
Computer Center Management	1,251	1,558
Computer Appreciation	11,545	16,915
Data Structures	873	831
Discrete Structures	145	218
Artificial Intelligence	15	0
Hybrid Computers	18	25
Switching Theory	0	331
Compiler Construction	307	344
Computer Organization, Intro.	1,585	3,307
Computer Organization, Advanced	127	464
Simulation	24	0
Graphics	129	236
Process Control	385	329
Numerical Analysis	2,991	1,364
Data Base Management Systems	167	662
Management Information Systems	1,071	684
File Organization	349	675
Advanced Course in Data Processing	3,905	4,020
Electric Accounting Machines (EAM)	22,118	1,896

250 associate level programs offered in associate level institutions.

Tables 9.6 and 9.7 give data about the course, Introduction to Data Processing, in associate level institutions. About 34% of the programs have more than 200 students in this course; 30% of the institutions have less than 50 students in the course. Reported class size is also shown, with 103 of the 250 programs reporting class sizes between 21 and 30. Only 7 programs report sizes above 50, while 81 have class sizes of 20 students or less. Most of the institutions (74%) have class sizes of 30 or below.

Table 9.6
Reported Course Enrollment: Introduction to Data Processing at Associate Level Institutions 1976-77

Total Enrollment In Course	Frequency	Percent Frequency
1 - 50	76	30.4
51 - 100	38	15.2
101 - 150	32	12.8
151 - 200	19	7.6
> 200	85	34.0

Table 9.7
Reported Average Class Size: Introduction to Data Processing at Associate Level Institutions 1976-1977

Class Size	Frequency	Percent Frequency
1 - 10	14	5.6
11 - 20	67	26.8
21 - 30	103	41.2
31 - 40	48	19.2
41 - 50	11	4.4
> 50	7	2.8

Mode of presentation is predominantly lecture/laboratory combination, indicated in 112 cases, with 31 institutions reporting lecture only.

Computer Appreciation. This course is generally offered as a course for nonmajors, to provide awareness of computers and how they are used in society. In 1969-70, there were 6,350 students in this course in 44 programs. By 1976-77, there were 9,303 students in the 106 associate level institutions reporting in the survey, an increase of 88% (8,500 to 16,000 students) in total estimated enrollments. It was offered in 113 of the 250 institutions. This increase occurred entirely in public institutions. The increases in this enrollment are probably caused by support of computer and society studies by the National Science Foundation, by the industry's concern for analysis of the impact of computers in and on society, by public concern for proper action in the handling of issues such as privacy and computer crime, and an awareness of a need for service courses for nonmajors.

Programming. The largest increase (forty-seven students per program) in the various programming courses from 1969-70 to 1976-77 took place in courses classified as BASIC or FORTRAN type language. Considerable increases are also evident in COBOL, up thirty-four students per program, and Programming Languages increased eight students per program. These increases probably reflect the increased use of time-sharing and interactive programming on minicomputers and microcomputers. As a group, programming courses increased by ninety students/reported program, reflecting an increased emphasis on teaching computer-based processing. Such increased emphasis at the associate level appears to be an attempt by faculty to raise the level of instruction to prepare students for jobs in computer programming, as opposed to preparation for jobs in general clerical, library, scheduling, and operations work.

Data Preparation. Enrollments in data preparation courses increased from approximately twelve per program in 1969-70 to twenty-one per program in 1976-77. In 1976-77, only nine courses were reported in private institutions; most instruction in this area occurs in public institutions with enrollments greater than 500 students. Only 101 of 250 associate level institutions with a program reported this course. This low proportion probably reflects the practice in some states of assigning data preparation instruction at the vocational-technical secondary level. Enrollments by size of institution and type of support follow the patterns of other data processing courses. Public colleges with enrollments between 2,500 and 10,000 students teach most of the students.

Electro-Mechanical Accounting Machines (EAM). A drastic decrease in enrollments in EAM courses is evident in associate level institutions between 1967 and 1977. In 1969-70, approximately 40 students per course were enrolled in 302 programs, by 1976-77, there were only twenty-one courses of this type offered among the 250 associate level institutions reporting computing programs. Only 1 private institution reported this course, with enrollment at 35. The 20 public programs offering it had 1,043 students taking the course. The sharp decrease in enrollments in this course reflects the general upgrading of the curriculum to keep abreast of changes in practice and usage, and is in line with the increase in emphasis on computer-based skills in processing data by means of computer programming.

Other courses. Although several courses such as numerical analysis, simulation, and artificial intelligence, showed slight decreases from 1970 to 1977, most courses showed increases in enrollments. Enrollment in operating systems courses increased from thirteen students per program to twenty-one, which probably reflects the increased emphasis recommended in this area by several studies and curriculum reports.[4,5,6] Increases in courses in data structures, discrete structures, computer organization, and computer architecture, for example, probably reflect increases in the number of majors in computer science. The appearance of a course in data communications may reflect an attempt to upgrade the associate level programs. It was offered to 1,045 students in thirty-two programs in 1976-77. Data were not gathered on courses in computer operations and the computer language RPG, both of which are common in two-year colleges.

Productivity of Programs

Reported associate level degrees awarded in 1977-78 were 5,913 from 335 programs, or approximately 18 graduates per program. It is estimated that approximately 10,170 graduates completed the associate level degree program nationwide that year. Data processing and information systems graduates account for a reported 3,861 graduates, or about 65% of the graduates, with computer science and computer programming accounting for about 25%. Table 9.8 shows the reported number of degrees awarded at the associate level for several inventories.

In 1967, an average of 7.3 graduates were produced from 142 reported associate level programs. By 1976-77, an average of 17.7 graduates were produced by 335 reported associate level programs. Average productivity of reported programs is presented in Table 9.9 for several of the survey periods. Note that programs in data processing, information systems, and computer programming are producing 20, 17, and 18, per program, respectively, while computer science programs are producing only 12. This may be caused partly by the fact that many of the computer science related programs are housed in mathematics departments, where facilities and instructors may be more limited.

In 1976-77, average production of associate level graduates in associate level institutions was seventeen per program. In the thirty-two baccalaureate level institutions offering associate level degrees, about seven associates were graduated per year. In the forty master's level institutions offering the associate degree, about five were graduated per year, and in the nine doctoral level institutions offering the associate level degree, about fourteen graduates were produced per year (see Table 9.10). Table

Table 9.8
Reported Degrees Awarded by Program Name 1966-67 through 1977-78

Program Name	66-67*	69-70*	70-71*	76-77*	77-78*
Computer Programming	78	688	819	564	691
Computer Science	58	259	435	663	777
Computer Technology	13	218	295	149	213
Data Processing	872	3285	3971	3058	3762
Information Systems		66	94	76	99
Total	1032	4516	5614	4774	5913

* See Table 9.1 for reciprocals of response rates or estimation ratios

Table 9.9
Average Productivity* of Reported Associate Degree Programs by Program Name
1966-67 through 1977-78

Program Name	66-67	69-70	70-71	76-77	77-78
Computer Programming	20	18	20	16	18
Computer Science	8	8	12	11	12
Computer Technology	2	10	13		
Data Processing	7	16	18	17	20
Information Systems		13	19	13	17
Total	7.3	15.0	17.4	14.5	17.7

*Average Productivity = $\frac{\text{\# Grads}}{\text{\# Programs}}$

Table 9.10
Reported Numbers of Associate Degrees Awarded by Degree Name and Level of Institution
1976-77

Program Name	Associate	Baccalaureate	Masters	Doctorate
Computer Engineering	0		8	
Computer Programming	568	11	12	0
Computer Science	486	85	75	1
Computer Science & Engineering	5	-	0	0
Computer Science Technology	47	33	0	5
Computer Technology	87	0	41	21
Data Processing	2859	40	62	97
Information Systems	65	2	6	3
Others	120	37	9	0
Totals	4237	208	213	127
# Grads/Program	16.9	6.5	5.3	

Number Reporting - 331

Table 9.11
Average Productivity of Reported Associate Degree Programs by Program Name and Level of Institution 1976–77

	1976-77 Level of Institution			
Program Name	Associate	Baccalaureate	Master	Doctorate
Computer Engineering	0	0	8.0	0
Computer Programming	17.8	3.7	6.0	0
Computer Science	15.2	6.1	4.7	1.0
Computer Science & Engineering	5.0	0	0	0
Computer Science Technology	9.0	16.5	0	5.0
Computer Technology	12.4	0	20.5	7.0
Data Processing	18.1	5.0	6.2	32.0
Information Systems	65.0	2.0	2.0	3.0
Others	8.6	9.3	9.0	0
Total	16.9	6.5	5.3	14.1

Number Reporting = 331

Note: Productivity = $\frac{\text{\# Associate Degrees Granted}}{\text{\# Programs}}$

9.11 shows the average productivity (reported number of graduates divided by number of associate level programs) by program name and level of institution. Refer back to Table 9.2 for figures on the total number of reported programs.

Historically, many associate degree programs in computing were initiated in the mid-1960s, based on the guidelines report produced by DHEW. They began with one or two teachers often shared by other departments. New programs often started with 30 to 40 students. Attrition led to the production of graduating class sizes on the order of 6 to 10 persons, producing the average of 7.3 by the 1967 survey. As new teachers were hired and larger entry level classes were possible, larger graduation classes were produced. However, limitations of equipment usage, laboratory schedules, number of faculty available, etc., prohibit the flow of massive numbers of students through programs. Programs which had only one computer used hands-on by students in 1967, later expanded their usage to a computer services center, and larger numbers could be accommodated. However, even with the advent of almost total on-line access to computers by means of time-sharing terminals and/or microcomputers, graduating class sizes will perhaps level off at about 25 or less over the next several years.

Staffing

The number of faculty teaching in the associate level programs is best measured in full-time-equivalent instructors, or FTE. However, a measure of support to the college and to the student clientele served is best measured by full-time instructors, FT. A comparison of these two gives a measure of the number of teachers short of full coverage by full-time instructors.

In 1967, at the 250 associate level institutions, there were approximately 3.6 FTE faculty per program and 3.42 FT faculty, leaving a shortfall of 0.18 per program. In 1971, there were less FTE, with 3.27 per program and 2.42 FT per program, making a shortfall of 0.85 per program. By 1976-77, there were 5.1 FTE per program, with only 2.76 FT, leaving a shortfall of 2.34 faculty per program! This means that only half of the courses were being taught by full-time personnel.

Comparisons made on an overall basis must be adjusted for course load. Faculty in associate level institutions most often teach fifteen semester hours per semester as a full-time assignment; in many baccalaureate institutions a full-time teaching load is twelve semester hours per semester, and in graduate level institutions it can vary from three to nine hours depending upon the other activities of the faculty members such as research grant and contract activities.

The shortage of full-time faculty in associate level programs is not unique to the associate level institutions, as shown in Table 9.12. Baccalaureate level institutions seem to be best staffed, with 1.91 FT per program covering an FTE of 2.59 (less than one instructor short). Master's level institutions are short of instructors by more than two persons, as also is the case at doctorate level institutions. However, at the graduate level institutions, shortages can be met by teaching assistants—an alternative

Table 9.12
Reported Faculty Resources in Associate Level Programs by Level of Institution
1976–77

Institution Level	Full-Time Equivalent Faculty	Full-Time Actual Faculty	Number of Faculty Short Per Program
Associate	1272 or 5.1/pgm	690 or 2.76/pgm	(2.34)
Baccalaureate	194 or 2.59/pgm	143 or 1.91/pgm	(0.68)
Masters	1046 or 5.36/pgm	595 or 3.95/pgm	(2.26)
Doctorate	2170 or 6.66/pgm	1345 or 4.13/pgm	(2.53)

not available to community colleges.

Even though enrollments are increasing, faculty numbers are getting smaller. Many part-time instructors teach computing at the associate level institutions, and graduate assistants teach at higher level institutions. Overall college declines are predicted for the late 1970s and 1980s, administrators are often fearful of hiring full-time faculty who are eligible for tenure. Cross-training, which brings personnel from a related department in the college and retrains that person to teach in an area of need, is often used to allow tenured faculty to be retrained to remain in service. Data about joint appointments in associate level institutions from the 1976-77 survey show a total of 109 joint appointments over the 250 programs, with 75 reported in the 158 data processing programs, and 19 in the 32 computer science programs. In baccalaureate level institutions, the proportion of joint appointments is even higher, with 62 in the 74 associate and baccalaureate programs, nearly 1 per program.

Among community and junior colleges, faculty holding the

Table 9.13

Reported Faculty with Ph.D–Computer Science or Ph.D–Other Based on FTE by Level of Institution 1976–77

Level of Institution	Name of Program	Faculty Members with Ph.D			
		Computer Science	Other	FTE	% Ph.D
Associate	Computer Programming	1	3	117	3.4
	Computer Science	0	10	118	8.4
	Data Processing	14	12	898	2.8
	All Programs	16	26	1270	3.3
Baccalaureate	Computer Programming	0	2	5	40.0
	Computer Science	13	39	76	68.4
	Data Processing	0	1	28	3.5
	All Programs	14	61	194	38.6
All Levels	Computer Programming	5	12	143	11.8
	Computer Science	493	695	2249	52.8
	Data Processing	28	33	1040	5.8
	All Programs	526	740	3432	36.8

Ph.D. degree are rare. Although persons who are already in associate level teaching may acquire the doctorate, in most cases they tend to move on to higher level institutions once that degree is attained. The 1976-77 survey data in Table 9.13 provides information about faculty with the Ph.D. in a computer-related field or in an "other" field. Since some of the Ph.D.'s are held by part-time faculty, these percentages are inflated.

Among FTE faculty in associate level institutions, approximately 3.3% hold the Ph.D. degree. Only 2.8% of faculty in those colleges who teach data processing programs hold the degree. In baccalaureate institutions, approximately 38.6% of the FTE faculty who teach in associate programs hold the Ph.D. degree. By program name, the proportion varies considerably: 68.4% of the computer science FTE faculty hold the Ph.D.; only 3.5% of the data processing FTE faculty hold the Ph.D.; and 40.0% of the computer programming FTE faculty hold the

Ph.D. More of the doctorates held by faculty in associate programs in baccalaureate level institutions are in "other" rather than in "computer science related" fields. Over all institutions of all levels the same contrast holds: 52.8% of the FTE faculty in computer science programs have the Ph.D., while only 5.8% of the FTE faculty in data processing have it.

To obtain an estimate of total computing faculty at the associate degree level one can multiply figures reported in the inventories by the inverse of the response ratio for associate degree institutions in each case. The proportion of Ph.D.'s per program and proportion of full-time faculty per program do not change during conversion. The total estimated faculty in each large group does appear larger than one might expect. Table 9.14 presents the summary data for the three years, 1966-67, 1969-70, and 1976-77.

One can conclude that Ph.D.'s are not being hired to teach in associate level programs. Those who do attain that degree probably move into other types of work or teach at a higher level after attaining it.

Facilities and Costs

Most associate level programs in associate level institutions have on-campus computing equipment. It is most often shared with the administrative computer services center, often with a loss of availability of hands-on experience. As colleges move toward equipment with capability for on-line access from terminals, student laboratories become a "terminals" com-

Table 9.14
Estimated Faculty at Associate Institutions 1966-67, 1969-70, 1976-77

Year	Number of Faculty	Total of Faculty FTE	Faculty Members with Ph.D	
			Computer Science	Other
1966-67	615	647	-	9
1969-70	1042	1406	10	14
1976-77	1189	2193	28	45

puter resources laboratory, often with demand access from display or typewriter terminals, and often with batch access provided by a remote job entry station, allowing immediate turnaround of programs to students. With the advent of the inexpensive microcomputer over the last few years, future use of the computer in the computer resources laboratory may well be from "stations" consisting of a small stand-alone microcomputer with a cassette diskette input device, capable of being used as a computer terminal for access to a larger time-sharing system.

The 1976-77 survey of courses provided for information about the facilities usage by course. Table 9.15 gives in-department and out-of-department costs per student for computing

Table 9.15
Cost of Computer Services per Student by Course in Associate Level Institutions 1976–77

Course	Reported Number of Students	$(1000) In-Dept.	$(1000) Out-of-Dept.	Cost/Student
Computer Appreciation	822	16	0	$19.00
Intro. BASIC, FORTRAN Types	2462	409	600	410.00
Intro. Programming, COBOL Type	1105	89	22	100.00
Intro. Programming	718	70	38	150.00
Advanced Programming	1026	81	12	91.00
Programming Languages	1085	84	25	100.00
Operating Systems	322	52	22	230.00
Data Structures	52	11	0	212.00
Intro. Comp. Organization	10	2	0	200.00
Graphics	60	3	0	50.00
Data Communications	125	10	0	80.00
Data Preparation	756	109	42	200.00
Electric Accounting Machines (EAM)	135	12	12	178.00
Intro. to Data Processing	6369	289	12	47.00
Systems Analysis, Intro. to	202	8	0	40.00
Computers & Accounting	60	1	0	17.00

Note: This data is drawn only from institutions that reported both enrollment and computer costs.

in courses in associate level institutions. The most expensive courses are those in operating systems, which cost up to $230 per student per course. The data preparation course requires $200 per student, but the introduction to data processing course requires computer costs of only $47 per student.

Although most associate level institutions have a computer facility, it is usually managed by computer services, defined as an out-of-department facility. Most introductory programming classes do use considerable out-of-department dollars, as shown on Table 9.15. However, in courses such as Operating Systems, Introduction to Computer Organization, Graphics, etc. the predominant computer in use is an in-department computer. Therefore, it must be assumed that departments are acquiring and maintaining their own computers again—perhaps a small minicomputer—to provide equipment on which to study operating systems without disturbing other users.

Conclusions and Recommendations

A 1975 survey[7] anticipated that the number of graduates from the post-secondary vocational and associate level programs might soon exceed the number needed in the labor market. This report recommended that weak programs be eliminated and others remaining be strengthened. The 1975 report assumed that associate degree institutions train students primarily for data entry, operations, and clerical data processing positions assuming that baccalaureate graduates are desired to meet the anticipated need for computer programmers. However, many graduates from the associate level, in fact, were placed into programmer positions. The 1975 report suggests that 360 students, or about 120 graduates per year, are needed to justify proper computing equipment costs. However, the 1976-77 survey reveals that programs are producing an average of only 18 graduates per year. Follow-up studies are needed to determine their level of placement so that better predictions can be made.

Community and junior colleges have survived explosive increases followed by a decrease in the number of programs, followed by a more steady increase of sufficient amount to reach earlier enrollment levels. Programs have adapted to offer a higher level of courses in computer-based processing with increased emphasis on computer programming, including interactive time-sharing demand processing. They are beginning to offer courses in operating systems and data communications. They are meeting the need for service courses by providing introduction to data processing courses, courses in computer appreciation or computers and society, and programming courses in several different languages and access arrangements. They are phasing out courses in EAM equipment, and are sharing the need for data preparation courses with the secondary schools.

Care must now be taken to ensure that the computing field is not saturated with too many low-level graduates who expect to get jobs in clerical and library functions in the data processing area, peripheral equipment operations, etc. In 1979, jobs are opening in more sophisticated programming areas that require more advanced programming techniques, knowledge of operating systems, utilities, etc. Associate degree programs that upgrade in order to supply higher-level personnel will probably survive and do well, providing a much needed employee to serve, or a graduate to transfer and continue on toward a baccalaureate degree. Those who do not upgrade may glut the market with unemployable graduates.

Community and junior colleges, however, are dangerously short of faculty, using part-time instructors to teach courses but losing much-needed services to students, curriculum development, and performance of articulation activities with industry and the four-year programs. Although retrenchment is occurring in almost all of higher education, programs which survive and do well will be those provided the necessary human support. Those without it may well survive, simply because the need for trained computer personnel is so great. However, the quality of graduates may suffer, and the understaffed associate degree programs may eventually disappear.

The associate level programs are providing a much-needed service to industry, government service institutions, and organizations by preparing students for jobs in the entry level computer programming areas. However, the associate level programs should continue to upgrade the quality of their programs and graduates, and should become more aligned to the baccalaureate programs in their area. More and more graduates will want to transfer into baccalaureate programs, as the level of sophistication of the work becomes higher, with less and less emphasis on operational and clerical data processing jobs. Those institutions which choose to offer data preparation courses should examine more modern data entry alternatives and teach them, and those who attempt to teach computer operations should analyze their market needs carefully to ensure that local jobs are available for graduates.

Notes

1. Curriculum Committee on Computer Science, "Curriculum '68: Recommendations for Academic Programs in Computer Science," *Communications of the ACM* 11 (March 1968):151-97.

2. J. Daniel Couger (Ed.), "Curriculum Recommendations for Undergraduate Programs in Information Systems," *Communications of the ACM* 16 (December 1973):727-49.

3. *Data Processing Technology, a Suggested Two-Year Post High School Curriculum*, U.S. Department of HEW, Office of Education (Washington, D.C.: U.S. Government Printing Office, 1973), Stock No. 1780-01240.

4. R. W. Brightman (Ed.), *The Computer and the Junior College Curriculum* (Washington, D.C.: American Association of Community and Junior Colleges, 1970).

5. Couger, "Curriculum Recommendations."

6. Curriculum Committee on Computer Science, "Curriculum '68."

7. John Hamblen, *Computer Manpower—Supply and Demand by States, 1975* (St. James, Mo.: Information Systems Consultants).

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10

Computer Science–Related Degree Programs at the Bachelor's Level

Gerald L. Engel

Introduction

The formalization of undergraduate four-year degree programs in computing is normally traced from the 1965 recommendations of the Association for Computing Machinery[1] and more completely from the 1968 recommendations of the same group.[2] Literature trends and developments since the publication of the 1968 recommendations are reviewed by Austing, Barnes, and Engel.[3]

Prior to the 1965 recommendations, several key articles appeared which helped to lay the foundation for the subsequent reports. Three of these, by Perlis,[4] Arden,[5] and Forsythe,[6] appeared in a special issue of *Communications of the ACM* in April 1964.

This same special issue of *Communications of the ACM* contained the results of the first major survey of computer science programs by Atchison and Hamblen.[7] In this survey, sent to 129 University Computer Center directors in North America and receiving ninety-three responses, it was determined that in 1963 there were twenty-eight computer-oriented degree pro-

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grams, with eighteen more planned. Of these programs, the following titles existed for bachelor's degree programs:

Mathematics and computing (College of Arts and Sciences)
Computing and statistics (College of Arts and Sciences)
Mathematical methods for digital computers (College of Arts and Sciences)
Computer science (College of Arts and Sciences)
Computer science program (College of Arts and Sciences)
Systems engineering (College of Engineering)
General engineering computer science option (College of Engineering)
Computer technology (College of Engineering)
Systems analysis and operations research (College of Engineering)
Computer and statistics (Department of Statistics, College of Business)
Women's curriculum in business administration; field of concentration electronic data processing (Department of Computer Center, College of Business)
Communication sciences (Department of Communication Sciences, College of Communication)

The vast majority of programs at this time were at the graduate level.

In this same survey, the respondents were asked for their preference for names of computer-related degree programs. Of the possible names suggested, the largest proportion was to name the program computer science, with the following titles well behind:

Systems engineering
Information processing
Data processing
Information science
Information systems science
Computer oriented mathematics
Applied mathematics
Applied science

Other names suggested included: systems analysis, syneonetics, communication sciences, computer technology, computer sciences and systems engineering, numerical analysis, cybernetics, and applied cybernetics. As will become clear later in this chapter, many of these names have remained, although computer science remains the predominantly used title for computer-related degree programs at the bachelor's level.

In subsequent surveys, funded by the National Science Foundation and culminating in the survey upon which this report is based, one sees a steady increase in computer-related bachelor's degree programs.[8-10] Estimates are calculated by multiplying reported totals by the ratio of the number of institutions in the population to the number of institutions responding. The number of degree programs and of graduates at all levels are summarized in Chapter 1 by Dr. Bruce Alcorn. Details on bachelor's degree programs reported may be found later in this chapter.

Trends Evident in Bachelor's Degree Programs, 1966-76

A list of institutions responding to the surveys is given for 1969-70 in Appendix A and for 1976-77 in Appendix B with projections for later years. The number of associate degree programs and growth patterns from 1966 to 1976, with projections to the present, are presented in Joyce Little's Chapter 9 (Figure 9.2). The names of the baccalaureate programs and the departments in which they are offered vary widely, as they did in the 1963 survey referenced in the introduction to this chapter.

Table 10.1 details the number of baccalaureate programs, by title, as they were reported in the years surveyed. The overall response rate for the 1966-67 survey was 79%, for 1969-70 it was 75%, and for 1976-77 it was 58%.

Throughout the three surveys the title of computer science maintains its dominance. It accounted for approximately 42% of the bachelor's programs in 1966-67; 60% in 1969-70 and 58% in 1976-77. The growth of the use of this title by 1966-67 may be attributed to the work of the ACM Committee on Curriculum in Computer Science (C^3S) in the early and mid-'60s

Table 10.1
Reported Bachelor's Degree Programs by Program Name 1966-67, 1969-70, 1976-77

Program Name	1966-67	1969-70	1976-77
Computer Engineering	0	1	7
Computer and Information Science	0	0	5
Computer Programming	0	6	4
Computer Science	30	90	181
Computer Science and Engineering	0	0	9
Computer Science Technology	0	0	3
Computer Technology	1	9	1
Data Processing	11	21	27
Information and Computer Science	0	1	5
Information Processing	0	0	1
Information Science	2	3	8
Information Systems	3	7	24
Mathematical Sciences	0	0	1
Others	22	2	31
Systems Analysis	2	3	1
Systems Computer Engineering	0	0	1
Statistics and Computer Science	0	0	1
Systems Engineering	1	7	1
Systems and Information Sciences	0	0	2
Systems Science	0	1	1
Totals	72	151	314

and finally their publication of "Curriculum '68." It may be noted in the survey periods, that the number of reported programs in data processing has remained relatively constant, while programs related to computer engineering and information systems have shown a significant increase. This latter phenomenon may be attributed to publication of curriculum recommendations in information systems,[11] and in computer science and engineering.[12] It also should be noted that there is a significant increase in the "other" category indicating some additional diversification of the programs.

Of the 342 bachelor's degree programs reported to be in place by 1978-79, 188 (55%) were bachelor's degree only; 35 (10%) offered the bachelor's degree and the associate degree; 59 (17%) offered the bachelor's degree and the master's degree (4 also offered the associate degree); and 60 (18%) offered the bachelor's degree, the master's degree, and the doctorate. The 342 reported programs were housed in 301 institutions: 267 schools offered only one program, 29 schools offered three programs, and 2 schools offered four programs.

Considering changes in offerings over the three academic years reported in the 1977 survey, several trends emerge. Three hundred baccalaureate programs showed no change. Twenty-six bachelor's degree programs were started in the period (nineteen where no previous programs existed, four where the associate degree was previously offered, and three where graduate programs were previously offered). In addition, twelve master's programs were started; one doctoral program was started; one combination master's and doctoral degree program was started; and one combination bachelor's, master's, and doctoral program was started in the period.

Public versus Private Institutions

Table 10.2 presents a breakdown of the reported bachelor's degree programs by size of enrollments of institutions and by control (public or private). From this table a significant increase in the total number of programs may be seen, both at the private and the public institutions. At public institutions this growth is spread over the 2,500-9,999 range, the 10,000-19,999 range,

Table 10.2

Reported Bachelor's Degree Programs by Size of Institution and Type of Control 1966-67, 1969-70, 1976-77

	Public Enrollment					Private Enrollment				
Year	Less than 500	500 to 2499	2500 to 9999	10,000 to 19,999	Greater than 20,000	Less than 500	500 to 2499	2500 to 9999	10,000 to 19,999	Greater than 20,000
1966-67	0	7	21	12	13	0	2	10	6	1
1969-70	0	12	43	30	21	0	18	19	4	4
1976-77	0	10	84	62	50	0	46	46	12	4

and the greater-than-20,000 range. In the private institutions the greatest growth in number of programs occured in the 500-2,499 range and the 2,500-9,999 range, indicating the increasing recognition of the importance of computer-related baccalaureate degree programs at the small liberal arts colleges and the smaller private universities. The growth by program titles, over the various classes of institutions fairly well mirrored the overall growth in the number of programs.

Enrollments

While representing a significant increase in the number of majors enrolled, the corresponding increase in the number of degree programs reported in the same period must be considered. The total of bachelor's and associate degree programs reported in 1966-67 was 214, 453 in 1969-70, and 644 in 1976-77. This yields ratios of majors enrolled to programs reported of 82.8 for 1966-67, 108.6 for 1969-70, and 94.8 for 1976-77. Thus the increase in enrollment, in many ways reflects the increase in program offerings. It is also of note that for the 1976-77 data, the program title of computer science accounted for 37% of the majors enrolled, and the program title data processing accounted for 36% of the majors enrolled.

Table 10.3 gives the reported numbers of majors enrolled in 1976-77 in the 301 institutions reporting the 342 bachelor's degree programs. Of these 342 programs, only 35 were offered at institutions also offering a computer-related associate degree program; therefore, these figures most closely represent majors enrolled in bachelor's degree programs.

From this table, it is evident that majors enrolled in computer science programs accounted for 62% of the total while data processing accounts for only 8% of the total. Keeping in mind that 35 of these institutions also offered the associate degree, it appears that the data processing title is almost exclusively that of the two-year programs. Similar results may be seen for programs in computer programming, computer science technology, computer technology, and information processing. It is also interesting to note that the only other program titles with significant enrollments are those in information systems and

Table 10.3
Reported Undergraduate Majors for 1976–77 in Institutions Offering the Bachelor's Degree

Program Title	Majors Enrolled
Computer Engineering	580
Computer and Information Science	670
Computer Programming	345
Computer Science	20,024
Computer Science and Engineering	1,165
Computer Science Technology	191
Computer Technology	620
Data Processing	2,556
Information and Computer Science	792
Information Processing	90
Information Science	334
Information Systems	1,894
Mathematical Sciences	100
Other	1,892
Systems Analysis	356
Systems and Computer Engineering	100
Systems and Computer Science	129
Systems Engineering	85
Systems and Information Science	208
Systems Science	180
Total	32,311

"other," each with 6% of the reported undergraduate majors.

The surveys provided course information for the academic years 1969-70 and 1976-77. All courses at all reporting institutions (1,177) in 1969-70 enrolled 552,393 students, while 1,409 institutions in 1976-77 enrolled 755,563 students. The ratios of the number of students enrolled in courses to the number of reporting institutions were 469 for 1969-70 and 536 for 1976-77.

Obtaining information on computer-related course enrollments for bachelor's degree programs was somewhat difficult. The category of institutions offering the bachelor's degree as the highest degree does not include those institutions offering bachelor's programs as well as graduate programs, and does include some institutions offering both associate and baccalaureate degree programs.

Noting that few institutions offered both the bachelor's and the associate degrees, the closest approximation to enrollments in computer-related courses including all bachelor's degree programs is derived by subtracting the enrollments at institutions offering the associate degree as the highest degree from the class of all institutions (see Table 10.4).

All courses showed an increase in enrollment with the exception of hybrid computers, switching theory, data preparation, unit record, and econometric simulation applications. Either such courses are disappearing from the curriculum or they are being absorbed into other programs.

To gain better insight into the course enrollments, one needs to adjust to the variation in response rate. An estimate of enrollment may be achieved by multiplying the reported values by the inverse of the response rate (0.75 for 1969-70; 0.58 for 1976-77). These results are given in Table 10.5.

In reviewing these estimates, it should be remembered that there were 1.96 times as many programs higher than the associate level in 1976-77 as there were in 1969-70. Thus the total estimated enrollment falls slightly short of being accounted for by the increase in the number of programs. In terms of specific courses, the following, recorded in both years, showed more than the 1.96 factor increase that reflects the increase in programs:

Table 10.4
Reported Course Enrollments for Institutions Offering Degrees Higher than Associate 1976-77

Course Description	1976-77
Computer Appreciation	23,457
Problem Solving Course in Humanities	6,946
Introductory Course in Compiler Language like FORTRAN, PL/1, BASIC or ALGOL	128,652
Introductory Course in a Language like COBOL	27,529
Problem Solving Course in Engineering or Scientific Applications	17,761
Introductory Course in Programming	55,731
Advanced Course in Programming	20,944
First Course in Computer Design	8,843
Advanced Course in Computer Design (Computer Architecture)	4,441
Programming Languages (Structures etc.)	9,966
Operating Systems (Systems Programming etc.)	10,372
Data Structures	9,765
Automata Theory	2,058
Simulation Applications (non-econometric)	2,474
Simulation Languages and/or Techniques	2,550
Artificial Intelligence (Heuristic Programming)	2,346
Hybrid Computers	352
Discrete Structures	4,131
Computer Organization	4,607
Switching Theory	2,650
Sequential Machines	793
Compiler Construction	3,919
Formal Language and Syntactic Analysis	1,894
Introduction to Computer Organization	6,557
Advanced Computer Organization	1,581
Information Storage and Retrieval	2,188
Computer Graphics	1,870
Computability	1,458

Table 10.4 Continued

Course Description	1976-77
Introductory Numerical Analysis (or Methods)	11,124
Advanced Numerical Analysis	3,315
Introductory Operations Research	6,416
Advanced Operations Research	2,419
Data Communications	1,271
Process Control	8,341
Data Preparation (Key Punch, Verifier, Data Entry)	1,052
Unit Record (EAM)	468
Introductory Course in Data Processing	44,904
Advanced Course in Data Processing	3,808
Problem Solving Course in Business Applications	17,572
Advanced Business Applications (Marketing, Finance, Production, etc.)	3,662
Introductory Systems Analysis (Business)	5,507
Large Scale Information Processing Systems	559
File Organization	1,451
Data Base Management	3,133
Information Systems Design (Introductory)	4,138
Information Systems Design (Advanced)	1,957
Management Information Systems	4,925
Management of Computer Centers and/or Information Processing Departments	1,038
Computers and Accounting (Including Auditing)	1,556
Econometric Simulation Applications	730
Instructional Design	40
Instructional Systems	218
Computer Based Instruction	760
Other	30,247
Description Not Coded	23,744
Totals	550,190

Table 10.5
Estimated Course Enrollments for Institutions Offering Degrees Higher than Associate 1969-70, 1976-77

Course Description	1969-70	1976-77
Computer Appreciation	14,820	38,939
Problem Solving Course in the Humanities	2,869	11,530
Introductory Course in Compiler Language like FORTRAN, PL/1, BASIC, or ALGOL	135,041	213,562
Introductory Course in a Language like COBOL	14,204	45,698
Problem Solving Course in Engineering or Scientific Applications	20,538	29,483
Introductory Course in Programming	51,006	92,513
Advanced Course in Programming	21,504	34,767
First Course in Computer Design	6,141	14,679
Advanced Course in Computer Design (Computer Architecture)	3,106	7,372
Programming Languages (Structures, etc.)	8,239	16,544
Operating Systems (Systems Programming, etc.)	9,744	17,218
Data Structures	4,675	16,210
Automata Theory	2,357	3,416
Simulation Application (non-econometric)	2,321	4,107
Simulation Languages and/or Techniques	3,252	4,233
Artificial Intelligence (Heuristic Programming)	1,853	3,894
Hybrid Computers	1,192	584
Discrete Structures	1,715	6,859
Computer Organization	4,770	7,648
Switching Theory	6,576	4,399
Sequential Machines	1,086	1,316
Compiler Construction	3,416	6,506
Formal Language and Syntactic Analysis	1,916	3,144
Introduction Computer Organization	4,343	10,885
Advanced Computer Organization	2,112	2,624
Information Storage and Retrieval	1,918	3,632
Computer Graphics	983	3,104
Computability	1,081	2,420

Table 10.5 Continued

Course Description	1969-70	1976-77
Introductory Numerical Analysis (or Methods)	14,159	18,466
Advanced Numerical Analysis	4,986	5,503
Introductory Operations Research	7,913	10,651
Advanced Operations Research	1,530	4,061
Data Communications	885	2,110
Process Control	941	13,846
Data Preparation (Key Punch, Verifier, Data Entry)	3,456	1,746
Unit Record (EAM)	3,432	777
Introductory Course in Data Processing	38,342	74,541
Advanced Course in Data Processing	4,096	6,321
Problem Solving Course in Business Applications	10,219	29,170
Advanced Business Applications (Marketing, Finance, Production, etc.)	3,796	6,079
Introductory Systems Analysis (Business)	5,611	9,142
Large Scale Information Processing Systems	450	928
File Organization	533	2,409
Data Base Management	743	5,201
Information Systems Design (Introductory)	2,654	6,869
Information Systems Design (Advanced)	1,341	3,249
Management Information Systems	4,544	8,176
Management of Computer Centers and/or Information Processing Departments	867	1,723
Computers and Accounting (Including Auditing)	2,477	2,583
Econometric Simulation Application	1,569	1,212
Instructional Design		66
Instructional Systems		362
Computer Based Instruction		1,262
Other	22,083	50,210
Description Not Coded	3,048	34,415
Totals	472,494	913,315

Computer appreciation
Problem solving course in the humanities
Introductory course in a language like COBOL
First course in computer design
Advanced course in computer design
Programming languages
Data structures
Artificial intelligence
Discrete structures
Introduction to computer organization
Computer graphics
Computability
Advanced operations research
Data communications
Process control
Problem solving course in business applications
Large scale information processing systems
Field organization
Data base management
Information systems design (introductory)
Information systems design (advanced)
Other
Description not coded

One sees in this list a number of special topics courses, many of the core courses of "Curriculum '68," several service courses (though not those normally associated with science and engineering), and business-oriented courses. Perhaps of most significance is the increase that may be seen in the categories of "other" and "description not coded." This could point to an increasing variability in the field, and a break from the "classical" course titles used in the survey, or to a lack of familiarity with the course titles by some individuals who filled out the reports.

The courses reported seem to follow the normal college course approach. Virtually all reported were either three to four semester hours or three to four quarter hours. Almost all the courses were lectures with some laboratory experience. The typical section size was around thirty. For institutions offering at most the bachelor's degree, the class size was around thirty for the service courses, less than twenty for the basic courses that might be associated with the major, and less than ten for advanced courses. Very few reported extensive use of television, visual aids, or individual study, although some such methods were indicated in the course category of "other."

Productivity

Between the 1967 and 1977 inventories of computing in higher education, the estimated number of bachelor's degrees awarded increased. Table 10.6 presents the estimated number of degrees awarded by program name.

A significant increase in the estimated number of degrees awarded may be seen in the programs named: computer engineering, computer science, data processing, information and computer science, information systems, "other," systems analysis, and systems and information science. On the other hand, there are decreases reported in the total numbers of degrees awarded in the programs named computer technology and systems engineering.

The proportion of bachelor's degrees awarded under the title of computer science began at 36% of all degrees awarded in 1966-67 and rose to 62% by 1976-77. In 1966-67, the other major title was option in electrical engineering (accounting for 157 degrees awarded in 1966-67 and included in "other" in Table 10.6 since it was not reported in subsequent surveys), accounting for 33% of the reported degrees awarded. By 1969-70, data processing accounted for the second highest number of reported degrees awarded with 17% of the total. Data processing continued to grow, although the percentages of the total decreased to 7% in 1976-77. The next major title according to number of degrees awarded was information systems with 7% in 1976-77, with information systems actually reporting more degrees awarded than data processing in 1976-77. The "other" category represented significant numbers in 1976-77, accounting for 5% of the reported degrees awarded.

As with the other data, a question arises as to whether or not the increasing number of degrees awarded is simply a reflection of the increasing number of degree programs. To investi-

Table 10.6
Reported Bachelor's Degrees Awarded by Program Name 1966-67, 1969-70, 1976-77

Program Name	1966-67	1969-70	1976-77
Computer Engineering	-	10	208
Computer and Information Science	-	-	206
Computer Programming	0	15	58
Computer Science	217	1,230	5,672
Computer Science and Engineering	-	-	344
Computer Science Technology	-	-	37
Computer Technology	25	76	15
Data Processing	61	360	631
Information and Computer Science	-	0	276
Information Processing	0	0	8
Information Science	0	35	129
Information Systems	24	115	647
Mathematical Sciences	-	-	35
Other	254	8	438
Systems Analysis	0	16	120
System Computer Engineering	-	-	30
Statistics and Computer Science	-	-	71
Systems Engineering	19	180	35
Systems and Information Science	-	0	88
Systems Science	-	32	116
Total	599	2,076	9,163

gate this, Table 10.7 presents, by program name, the reported numbers of degrees awarded divided by the reported number of bachelor's degree programs.

All programs show a significant increase over the 1969-70 to 1976-77 period, demonstrating a clear increase in the number of degrees awarded over and above the increase in the number of programs. The increases are rather uniformly spread over the program names; the greatest fluctuations are in cases where there are relatively few programs. Only four program titles showed decreases, and, in all cases, few programs were involved.

Staffing

Data on the estimated number of faculty for all institutions surveyed is given in Table 10.8. All estimates in this section are based on the reciprocal of the response rate (79% for 1966-67, 75% for 1969-70, and 58% for 1976-77). An approximation of the number of faculty involved in teaching at the bachelor's level may be obtained by subtracting the corresponding values for institutions offering, at most, the associate degree from those given in Table 10.8. These results, reported in Table 10.9, obviously include faculty who teach in both graduate and undergraduate programs. Since the data cannot be broken down to separate graduate and undergraduate faculty, trends and proportions indicated here should be applied to both baccalaureate and graduate programs.

Table 10.10 normalizes these results by dividing the numbers given in Table 10.9 by the corresponding estimates of degree programs to indicate how increases relate to the increase in the number of degree programs. From this table, we see that faculty per program has remained relatively constant since 1969-70, with the number of FTE faculty per program actually decreasing. The number of faculty with Ph.D.'s in computer science showed a small increase while faculty with Ph.D.'s in other fields who teach in computer-related programs showed a slight decrease.

It is interesting to look at the faculty resources for computing in a subset of the colleges offering baccalaureate programs. In considering institutions that offer at most the bachelor's

Table 10.7
Average Productivity of Reported Bachelor's Degree Programs by Program Name 1969-70, 1976-77

Program Name	1969-70	1976-77
Computer Engineering	8.0	17.9
Computer and Information Science	-	24.8
Computer Programming	2.0	8.8
Computer Science	10.8	18.9
Computer Science and Engineering	-	23.0
Computer Science Technology	-	7.3
Computer Technology	6.7	9.0
Data Processing	13.6	14.1
Information and Computer Science	0	33.2
Information Processing	-	5.0
Information Science	9.3	9.8
Information Systems	13.0	16.2
Mathematical Sciences	-	21.0
Other	3.0	8.5
Systems Analysis	4.3	72.0
Systems Computer Engineering	-	18.0
Statistics and Computer Science	-	43.0
Systems Engineering	20.4	21.0
Systems and Information Science	-	26.5
Systems Science	25.0	70.0
All Programs	10.9	17.6

Note: Productivity = # Degrees Granted ÷ # Programs

Table 10.8
Estimated Faculty, All Institutions
1966-67, 1969-70, 1976-77

Year	Number of Faculty	Total Faculty FTE	Faculty Members with Ph.D. Computer Science	Other
1966-67	1,243	2,046	*	852
1969-70	2,875	4,625	463	1,051
1976-77	4,784	8,072	1,259	1,898

Table 10.9
Estimated Faculty at All Institutions Offering Degrees Higher than Associate
1966-67, 1969-70, 1976-77

Year	Full Time Faculty	Total Faculty FTE	Faculty Members with Ph.D Computer Science	Other
1966-67	628	784	*	843
1969-70	1,833	3,219	453	1,037
1976-77	3,595	5,879	1,231	1,853

Table 10.10
Estimated Faculty per Program for All Institutions Offering Degrees Higher than Associate
1966-67, 1969-70, 1976-77

Year	Full Time Faculty	Total Faculty FTE	Faculty Members with Ph.D. Computer Science	Other
1966-67	2.55	3.18	*	3.43
1969-70	4.06	7.14	1.00	2.30
1976-77	4.07	6.65	1.39	2.10

*Not Reported

degree, one finds the greatest contribution to the total from institutions with enrollments between 500 and 10,000 students. Table 10.11 reports the estimated faculty per program for these institutions.

From these figures we may conclude that at the small liberal arts institutions, the faculties remain very small, hardly keeping up with the increase in the number of programs. It may also be observed that virtually none of the faculty have doctorates in computer science, and relatively few have doctorates in any field.

Costs of Computing Courses

For the courses discussed in this chapter, costs of computer services per student are given for 1969-70 and 1976-77 in Table 10.12. These are calculated for the class of all institutions less those offering at most the associate degree (thus approximating the costs associated with bachelor's programs). As in the case of staffing data, trends and proportions evident in this data should be applied to both graduate and undergraduate baccalaureate programs. It also should be noted that for the 1969-70 data, the costs per student are derived from total costs reported divided by total enrollment reported, while for 1976-77 the cost per student was calculated only from those institutions reporting both enrollment and costs. This was necessary since, in the 1969-70 data, this material was more consistently reported while it was not in the 1976-77 data.

By comparison in this manner, we see an increase in cost of computing services per student of approximately 44% over the two reporting periods. Certainly some of this may be accounted for by the more accurate manner in which the latter costs were calculated; however, the result that costs have increased remains.

Decreases in costs were reported only in the case of twelve courses. Of these five were applications courses (problem-solving course in the humanities, problem-solving course in engineering or scientific applications, simulation applications [non-econometric], problem-solving course in business applications, econometric simulation applications), four were advanced courses which had somewhat limited enrollment (automata theory, computer graphics, computability, and large scale infor-

Table 10.11
Estimated Faculty per Program at Selected Institutions Offering the Bachelor's Degree but No Higher Degree
1969-70, 1976-77

	500 - 2499 Enrollment				2500 - 9999 Enrollment			
			Ph.D.'s				Ph.D.'s	
Year	Full Time Faculty	Faculty FTE	Computer Science	Other	Full Time Faculty	Faculty FTE	Computer Science	Other
1969-70	2.21	2.71	0.29	0.67	4.33	5.33	0.00	0.67
1976-77	2.21	2.74	0.17	1.10	2.61	4.11	0.39	0.72

Table 10.12
Cost of Computer Services per Student by Courses in all Institutions Offering Higher than the Associate Degree 1969-70, 1976-77

Course Description	1969-70	1976-77
Computer Appreciation	$ 20.91	$ 40.25
Problem Solving Course in Humanities	90.91	20.78
Introductory Course in Compiler Language like FORTRAN, PL/I, BASIC, ALGOL	41.95	60.59
Introductory Course in a Language like COBOL	42.14	57.93
Problem Solving Course in Engineering or Scientific Applications	45.40	34.65
Introductory Course in Programming	39.48	47.23
Advanced Course in Programming	113.44	62.28
First Course in Computer Design	19.49	38.51
Advanced Course in Computer Design (Computer Architecture)	32.45	48.01
Programming Languages (Structures etc.)	60.87	70.54
Operating Systems (Structures etc.)	74.74	132.46
Data Structures	75.47	200.82
Automata Theory	16.57	15.62
Simulation Applications (non-econometric)	61.89	52.63
Simulation Languages and/or Techniques	73.61	102.04
Artificial Intelligence (Heuristic Programming)	43.51	850.75
Hybrid Computers	49.68	212.22
Discrete Structures	24.98	34.48
Computer Organization	40.94	70.21
Switching Theory	$ 9.39	$172.73
Sequential Machines	12.76	157.89
Compiler Construction	51.27	257.53
Formal Languages and Syntactic Analysis	39.20	364.13
Introductory Computer Organization	39.74	39.39
Advanced Computer Organization	21.48	131.43
Information Storage and Retrieval	57.16	107.06
Computer Graphics	106.41	18.92
Computability	16.32	10.00

Table 10.12 Continued

Course Description	1969-70	1976-77
Introductory Numerical Analysis (or methods)	62.12	67.78
Advanced Numerical Analysis	42.20	53.48
Introductory Operations Research	21.82	24.51
Advanced Operations Research	23.08	55.56
Data Communications	15.67	93.92
Process Control	26.77	62.54
Data Preparation (Keypunch, Verifier, Data Entry...)	5.10	80.00
Unit Record (EAM)	23.86	-
Introductory Course in Data Processing	32.44	21.48
Advanced Course in Data Processing	27.07	50.34
Problem Solving Course in Business Applications	23.18	11.09
Advanced Business Applications (Marketing, Finance, etc.)	$ 21.91	$ 23.58
Introductory Systems Analysis (Business)	17.07	49.62
Large Scale Information Processing Systems	47.62	45.69
File Organization	96.93	166.10
Data Base Management	15.25	133.68
Information Systems Design (Introductory)	23.74	76.92
Information Systems Design (Advanced)	29.14	183.91
Management Information Systems	15.81	44.72
Management of Computer Centers and/or Information Processing Depts.	10.80	39.68
Computers and Accounting (Including Auditing)	6.61	142.12
Econometric Simulation Applications	12.05	11.28
Instructional Design	-	-
Instructional Systems	-	39.11
Computer Based Instruction	-	97.74
Other	36.57	81.34
Description Not Coded	18.60	39.23
Total Average over all courses	$ 42.25	$ 60.82

mation processing systems), and three would be more standard undergraduate courses (advanced course in programming, introductory computer organization, and introductory course in data processing).

Conclusions and Projections

There is a dramatic increase in the number of bachelor's degree programs over the reporting period. A 554% increase in the estimated number of bachelor's programs is seen between the 1966-67 data and the 1978-79 data. A 197% increase may be seen in going from the 1969-70 data to the 1978-79 data. Much of this may be attributed to the formalizing of computer science programs in the late '60s, however, the latter increase shows that the estimated number of bachelor's degree programs has almost tripled from 1969-70 (after the publication of "Curriculum '68") to the present. It is interesting to note that in 1978-79 the estimated number of bachelor's degree programs exceeded the number of associate degree programs, thus becoming the most commonly offered degree. All indications are that this increasing trend in the number of bachelor's degree programs will continue with the continuing demand of the industry for people with this level of training.

Significant growth in the number of bachelor's degree programs is seen at all sizes of institutions and in both public and privately supported institutions. It is of note, however, that the greatest increases are reported at the smaller institutions (less than 10,000 enrolled), and that the rate of increase is greater at the privately supported institutions. Thus, computer-related degree programs are moving into these areas, and again this would point to further expansion of the number of programs since many such institutions do exist without such programs at this time. This increase would appear to reflect a desire on the part of the smaller institutions to introduce more viable and attractive programs that would respond to the job market.

There was a 1,961% increase in the estimated number of bachelor's degrees awarded between 1966-67 and 1977-78. Again, much of this may be attributed to the events in computer science education in the late 1960s; however, the increase in more recent years is also significant. For example, there was a 29% increase in the estimated number of bachelor's degrees awarded between 1976-77 and 1977-78. The bachelor's degree became the most common of the four degrees awarded, surpassing the associate degree, in 1976-77, and the rate of increase of bachelor's degrees awarded now exceeds that of the associate degree.

Overall course enrollments reported showed significant increase over the reporting periods. Here again we see the effect of the beginnings of computer science programs in the late '60s. Much of the increase may be associated with the increase in the number of degree programs, since we see only a 14% increase in enrollments per institution in computer-related courses between 1969-70 and 1976-77.

Computer science has proved to be by far the most common title for computer-related degree programs at the bachelor's level. Some increase may be seen in programs in information systems and computer science and engineering. This may be accounted for by the efforts to develop and publish recommendatons for curriculum at the undergraduate level in information systems and in computer science and engineering. These kinds of programs should have increasing impact in coming years as these programs become better established and accepted, however computer science will remain the primary program title.

Like the number of bachelor's degree programs, enrollments are primarily concentrated in computer science with information systems and "other" programs a distant second. This latter is quite interesting, demonstrating that there is still enough change in the field that a significant number of programs do not easily fit into predefined molds of the titles listed on the survey form. It is also important to note that enrollments in bachelor's degree programs in data processing, computer programming, computer science technology, computer technology, and information processing are falling off.

All courses listed in the survey forms increased in estimated enrollments with the exception of hybrid computers, switching theory, data preparation, unit record, and econometric simulation applications. The increases were quite small, however, in the case of the courses sequential machines, advanced computer organization, introductory numerical analysis, advanced numerical analysis, and computers and accounting. If one will make concessions, such as calling numerical analysis an application of computer science, these courses may all be classified within the categories of engineering, applications, and "classical" data processing.

If one considers the increase in the number of programs, we find the most significant increase in the category of "other courses" and "description not coded." This no doubt is caused by a combination of responders having difficulty in completing the forms, and to some extent it also reflects the diversification of the field and the fact that many of the courses associated with software engineering, computer science and engineering, and many other new courses were not reflected in survey titles.[13]

The courses normally attributed to the "Curriculum '68" type program maintained relatively constant enrollments, taking into account the increase in the number of programs. Those courses associated with information systems programs showed significant increase. Standard service courses such as those for sciences and engineering showed a slight decrease relative to the increase in the number of programs, while special service courses such as those for the humanities showed increases. This indicates that programming instruction is most likely being offered within many of the established user departments, while newer application areas are being explored by computer science departments.

Course formats at the bachelor's degree level remain fairly classical. The typical course is three to four semester or quarter hours, involves some type of laboratory experience, and does not rely, to any major extent, on specialized teaching aids.

The estimated number of bachelor's degrees awarded increased significantly over the periods studied. This increase is in fact a real one, since it represents an increase in per program productivity demonstrating that more bachelor's degree students are completing their programs.

There is a slight increase in the number of faculty relative to the number of programs between 1966-67 and 1976-77. The number of full-time faculty per program, however, remained relatively constant from 1969-70 and 1976-77, and the number of FTE per program actually decreased in this period. The number of faculty per program with doctoral degrees in computer science increased, though not significantly, with a corresponding decrease in faculty with doctorates in other fields. This, of course, reflects the fact that individuals with advanced degrees in computer science have become more available during the period, but certainly there are not enough to meet the demand.

The difficulty of obtaining qualified faculty in computer science is perhaps best seen at institutions offering the bachelor's degree as the highest degree (the smaller colleges and universities). There are no increases in faculty per program at these institutions, and few faculty members have doctorates in computer science. Thus, while there appears to be a most significant increase in programs at smaller institutions, the faculty at the institutions may not have as much training as would be desired. Since there does not appear to be enough qualified faculty members to staff all the existing graduate programs, this in turn points to a major need for alternate means of training individuals to teach at the smaller schools.

Costs of computer services for the computer-related courses showed a significant increase over the period studied. Some of this may be accounted for by the difference in the manner in which costs were calculated. Some of it may also be seen in a move in many departments to acquire departmental computers thus causing an initial jump with the purchase of the equipment. It would appear that more institutions will be going to departmental equipment for at least the more advanced courses, and with the availability of the microcomputers these costs should stabilize or decrease.

Computer-related degree programs at the bachelor's level and enrollment in them are significantly increasing and should continue to do so. The greatest problem to successful growth appears to be in ways in which faculty may be trained or retrained to teach at this level.

Notes

1. Curriculum Committee on Computer Science (C^3S), "An Undergraduate Program in Computer Science, Preliminary Recommendations," *Communications of the ACM* 8 (September 1965):543-52.

2. Curriculum Committee on Computer Science (C^3S), "Curriculum '68, Recommendations for Academic Programs in Computer Science," *Communications of the ACM* 11 (March 1969):151-97.

3. Richard H. Austing, Bruce H. Barnes, and Gerald L. Engel, "A Survey of the Literature in Computer Science Education Since Curriculum '68," *Communications of the ACM* 20 (January 1977):13-21.

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7. William F. Atchison, and John W. Hamblen, "Status of Computer Sciences Curricula in Colleges and Universities," *Communications of the ACM* 7 (April 1964):225-77.

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9. John W. Hamblen, *Inventory of Computers in U.S. Higher Education, 1969-70: Utilization and Related Degree Programs* (Washington, D.C.: U.S. Government Printing Office, 1972), out of print.

10. John W. Hamblen, *Computer Manpower—Supply and Demand—By States* (St. James, MO.: Information Systems Consultants, 1975, 1979).

11. Daniel J. Couger (Ed.), "Curriculum Recommendations for Undergraduate Programs in Information Systems," *Communications of the ACM* 16 (December 1973):727-49.

12. T. Cain (Ed.), *Model Curriculum in Computer Science and Engineering*, IEEE Computer Society, January 1977.

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11

Computer Science–Related Degree Programs at the Graduate Level

Richard H. Austing

Introduction

Graduate degree programs in computer science-related areas existed prior to the formalization of undergraduate four-year degree programs. In the first major survey of computer science programs conducted in 1963 by Atchison and Hamblen,[1] as reported in the preceding chapter, twenty-eight computer-oriented degree programs were reported with eighteen more planned. This survey was sent to 129 university computer center directors in North America and responses were received from 93 of them. The vast majority of programs were at the graduate level. The following titles were reported for graduate degree programs:

- In a College of Arts and Sciences:
  Mathematics and computing
  Computing science
  Computer science
  Computer oriented mathematics
  Master of Science in computer science

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  - Statistics
  - Computer and information science
  - Information and system science
- In a College of Engineering:
  - Computer option
  - Systems engineering
  - General engineering computer science option
  - Master of Science in computer science
  - System analysis and operations research
  - Systems and communication sciences
  - Computer science option
- In a College of Business:
  - Mathematical methods and computers
  - Quantitative business analysis
- In a Graduate School:
  - Numerical analysis and advanced computer techniques
  - Graduate degrees: Diploma in computing or data processing
- In a College of Communication:
  - Communication sciences
- In a Computation Center:
  - Information processing systems analysis

In answer to the 1963 survey's request for preferred names of computer-related degree programs, the respondents overwhelmingly cited computer science. There were other possible titles included but none were specified by a significant number of respondents. In three later surveys, including the 1976-77 inventory analyzed in this book, computer science remains the predominant choice of name for graduate degree programs, just as it does for bachelor's degree programs.

General response to the 1966-67, 1969-70, and 1976-77 surveys is analyzed in Chapter 1 by Bruce Alcorn. Tables 11.1 and 11.2 illustrate patterns of change in number of graduate programs and number of graduate degrees awarded between 1967 and 1977.

Total reported course enrollments at the graduate level have increased significantly during the past ten years. Details and dis-

Table 11.1
Estimated Number of Degree Programs by Level 1966–67, 1969–70, 1976–77

Year	Master's	Doctorate
1966-67	98	58
1969-70	155	98
1976-77	224	119

Table 11.2
Estimated Total Numbers of Degrees Awarded by Levels 1966–67, 1969–70, 1976–77

Year	Total Master's Degree	Total Doctoral Degree	Master's Degree By Program	Doctoral Degree By Program
1966-67	742	174	7.6	3.0
1969-70	1442	307	9.3	3.1
1976-77	3161	345	14.1	2.9

cussion of the distribution of graduate degree programs and courses will be given in the sections which follow.

Trends Evident in Graduate Degree Programs, 1966-77

A list of the institutions reporting graduate degree programs, and the names of the programs, organized by state, is given in Appendices A and B. The names of programs and the departments in which they are offered vary widely, as they did in the 1963 survey referenced in the introduction to this chapter.

Tables 11.3 and 11.4 detail the reported number of graduate programs in computing as they appeared in the years surveyed. The response rates for the different surveys were: 79%

Table II.3
Reported Master's Degree Programs by Program Name 1966-67, 1969-70, 1976-77

Program Name	1966-67	1969-70	1976-77
Computer Engineering	N/R	1	6
Computer and Information Science	N/R	0	2
Computer Programming	0	0	0
Computer Science	37	76	81
Computer Science and Engineering	N/R	0	9
Computer Science Technology	N/R	0	1
Computer Technology	0	3	0
Data Processing	4	6	2
Information and Computer Science	N/R	2	2
Information Processing	1	0	0
Information Science	9	7	3
Information Systems	1	5	8
Other	3	0	10
Options in...	21	0	0
Systems Analysis	0	3	0
System Computer Engineering	N/R	0	1
Statistics and Computer Science	N/R	0	0
Systems Engineering	1	12	2
Systems and Information Science	N/R	1	1
System Science	N/R	0	2
Total	77	116	130

N/R = Not Recorded in Survey

Table 11.4
Reported Doctoral Degree Programs by Program Name 1966-67, 1969-70, 1976-77

Program Name	Masters Degrees 1966-67	Masters Degrees 1969-70	Masters Degrees 1976-77	Doctoral Degrees 1966-67	Doctoral Degrees 1969-70	Doctoral Degrees 1976-77
Computer Engineering	N/R	3	74	N/R	1	14
Computer & Information Science	N/R	N/R	129	N/R	N/R	9
Computer Programming	0	0	0	0	0	0
Computer Science	307	1186	1868	43	249	234
Computer Science and Engineering	N/R	N/R	251	N/R	N/R	31
Computer Science Technology	N/R	N/R	26	N/R	N/R	0
Computer Technology	0	5	0	0	3	0
Data Processing	17	12	31	1	0	5
Information & Computer Sciences	N/R	3	120	N/R	17	9
Information Processing	4	0	0	0	0	0
Information Science	81	45	215	4	15	5
Information Systems	4	32	186	0	1	22
Other	116	0	187	19	0	14
Options in...	207	N/R	N/R	108	N/R	N/R
Systems Analysis	0	8	0	0	0	0
System Computer Engineering	N/R	N/R	17	N/R	N/R	0
Systems Engineering	19	113	26	3	13	0
Systems & Information Science	N/R	24	5	N/R	5	3
Systems Science	N/R	0	3	N/R	0	0
Total	755	1442	3161	174	305	345

N/R = Not Recorded

for 1966-67, 75% for 1969-70, and 58% for 1976-77.

Clearly, computer science is the predominant name for graduate degree programs. It accounted for approximately 49% of the master's degree programs in 1967; 66% in 1969-70; and 62% in 1976-77. Percentages for doctoral degree programs are similar: 48% in 1967; 68% in 1969-70; and 58% in 1976-77. The growth of the use of this title between 1967 and 1969-70 can be attributed to the use of the term in the publication of "Curriculum '68."[2] Although the numbers of programs with titles other than computer science are too small to draw any conclusions, it can be noted that increases are reported in the use of the titles computer engineering, computer science and engineering, and information systems. Decreases occurred in the use of the titles computer technology, data processing, information science, systems analysis, and systems engineering. The decrease in the use of "option in . . ." seems to be reflected in the increased use of titles in the "other" category.

Of the 69 doctoral degree programs reported in 1976-77, only 1 (1%) was doctoral degree only; 13 (19%) offered the doctoral degree and the master's degree; and 55 (80%) offered the doctoral degree, the master's degree, and the bachelor's degree. Of the remaining 62 master's degree programs reported in 1976-77, 16 (12% of the total 130 master's degrees reported) were master's degrees only; 45 (35%) offered the master's degree and the bachelor's degree; and 2 (1%) offered the master's degree, the bachelor's degree, and the associate degree. The 148 master's degree programs reported in 1978-79 were housed in 127 institutions. There were 109 schools with only 1 program; 14 with 2 programs; and 4 with 3 programs.

There were twenty-four changes in offerings over the three academic years reported in the 1976-77 survey. One doctoral degree program was started where a master's degree program already existed and one was started where master's degree and bachelor's degree programs already existed; one doctoral degree and master's degree program was started where only a bachelor's degree program already existed and one combination doctoral degree, master's degree, and bachelor's degree program was started where no degree program previously existed. Fifteen master's degree programs were started (eleven where only the bachelor's degree program, two where the bachelor's degree and the associate degree program, and two where no degree program previously existed). One combination master's degree and bachelor's degree program was started where no degree program previously existed; one bachelor's degree program was started where only a master's degree program already existed; and one bachelor's degree program was started and two were discontinued where a master's degree and a doctoral degree program already existed.

Public versus Private Institutions

Table 11.5 gives a breakdown for the three-year period included in the 1977 survey of master's and doctoral degree programs by enrollment and control of institutions.

From 1976 to 1978, a 15% increase in the total number of reported master's degree programs at public institutions occurred. Growth is distributed over all sizes of institutions except those having less than 500 students. The increase in master's degree programs in private institutions (1%) occurred entirely in those institutions that enrolled 2,500 to 9,999 students. Increases in master's degree programs are consistent with the increases in bachelor's degree programs noted in the preceding chapter by Gerald Engel. Relatively little increase in doctoral degree programs occurred within public or private institutions. Small increases did occur in public institutions having greater than 20,000 students and in private institutions enrolling 2,500 to 9,999 students. The increases in the large public institutions follow a pattern established between 1966 and 1976, and the increase in small-to-medium size private liberal arts schools is consistent with the growth in bachelor's and master's degree programs in those institutions.

Enrollments

Table 11.6 gives the number of graduate students reported to be enrolled in the various programs in the years included in the three inventories 1966-67, 1969-70, and 1976-77.

The number of graduate students more than doubled during the ten-year period covered by these surveys. During the

Table II.5

Reported Graduate Degree Programs by Size of Institution and Control 1976-77, 1977-78, 1978-79

	Public Enrollment						Private Enrollment						
Year	Less than 500	500 to 2499	2500 to 9999	10000 to 19999	Greater than 20000	Total	Less than 500	500 to 2499	2500 to 9999	10000 to 19999	Greater than 20000	Total	Grand Total
							Masters Degree Program						
1976-77	0	3	11	31	48	93	0	3	21	10	3	37	130
1977-78	0	3	13	33	50	99	0	3	23	10	3	39	138
1978-79	0	4	15	37	51	107	0	3	25	10	3	41	148
							Doctoral Degree Program						
1976-77	0	1	4	9	35	49	0	2	10	5	3	20	69
1977-78	0	1	4	9	35	49	0	2	11	5	3	21	70
1978-79	0	1	4	9	38	52	0	2	11	5	3	21	73

Table 11.6
Reported Total Graduate Majors Enrolled by Program Name 1966-67, 1969-70, 1976-77

Program Title	1966-67	1969-70	1976-77
Computer Engineering	N/R	9	205
Computer & Information Science	N/R	N/R	236
Computing Programming	0	63	0
Computer Science	1429	4725	5525
Computer Science & Engineering	N/R	N/R	754
Computer Science Technology	N/R	N/R	40
Computer Technology	0	53	0
Data Processing	92	159	48
Information & Computer Science	N/R	585	217
Information Processing	23	0	0
Information Science	627	240	338
Information Systems	8	241	431
Other	125	0	435
Options in...	1597	N/R	N/R
Systems Analysis	0	132	0
System Computer Engineering	N/R	N/R	20
Systems Engineering	48	402	22
Systems & Information Science	N/R	199	25
Systems Science	N/R	0	30
Total	3949	6808	8326

N/R = Not Recorded

same period, the number of graduate degree programs increased from 123 in 1966-67 to 189 in 1969-70 to 199 in 1976-77. The reported numbers of graduate students enrolled per program offered are thirty-two in 1966-67, thirty-six in 1969-70, and forty-two in 1976-77. The increase in total enrollment results from both an increase in the number of graduate programs and an increase in students per program. The data also show that a significant percentage of graduate students major in computer science programs (66% in 1976-77) while the next most significant program is computer science and engineering (9%). No other program has more than 5% of the total graduate student majors.

Course enrollment information provided in the inventories did not distinguish graduate student enrollment and undergraduate student enrollment. Since most of the institutions which reported graduate degree programs also reported bachelor's degree programs, it is not meaningful to create tables different from Tables 10.5-10.7 in Gerald Engel's chapter. Also, Dr. Engel's discussion of the data in the tables offers as detailed a breakdown as is possible with the survey data. Consequently, no additional discussion will be included in this chapter on graduate course enrollment.

Productivity

As a measure of productivity of graduate programs in computing, Tables 11.7 and 11.8 present data on the total number of graduate degrees granted and the number of degrees granted per program for the three survey years 1966-67, 1969-70, and 1976-77.

During the ten-year period 1966-76, the estimated number of master's degrees granted quadrupled and the number of doctorates doubled. The number of master's degrees awarded in computer science increased to approximately 82% of all master's degrees awarded in 1969-70, but in 1976-77 these represent only 59% of the total. Programs which also showed a significant percentage of master's degrees awarded in 1976-77 are: computer and information science (4%), computer science and engineering (8%), information and computer science (3%), information sci-

Table 11.7

Estimated Number of Graduate Degrees Awarded by Program Name 1966-67, 1969-70, 1976-77

Program Name	Masters Degrees			Doctoral Degrees		
	1966-67	1969-70	1976-77	1966-67	1969-70	1976-77
Computer Engineering	N/R	3	74	N/R	1	14
Computer & Information Science	N/R	N/R	129	N/R	N/R	9
Computer Programming	0	0	0	0	0	0
Computer Science	307	1186	1868	43	249	234
Computer Science and Engineering	N/R	N/R	251	N/R	N/R	31
Computer Science Technology	N/R	N/R	26	N/R	N/R	0
Computer Technology	0	5	0	0	3	0
Data Processing	17	12	31	1	0	5
Information & Computer Sciences	N/R	3	120	N/R	17	9
Information Processing	4	0	0	0	0	0
Information Science	81	45	215	4	15	5
Information Systems	4	32	186	0	1	22
Other	116	0	187	19	0	14
Options in...	207	N/R	N/R	108	N/R	N/R
Systems Analysis	0	8	0	0	0	0
System Computer Engineering	N/R	N/R	17	N/R	N/R	0
Systems Engineering	19	113	26	3	13	0
Systems & Information Science	N/R	24	5	N/R	5	3
Systems Science	N/R	0	3	N/R	0	0
Total	755	1442	3161	174	305	345

N/R = Not Recorded

Table II.8
Average Productivity of Graduate Programs by Program Name 1966-67, 1969-70, 1976-77

Program Title	Masters Degrees			Doctoral Degrees		
	1966-67	1969-70	1976-77	1966-67	1969-70	1976-77
Computer Engineering	N/R	2.0	7.2	N/R	.3	2.7
Computer & Information Science	N/R	N/R	37.5	N/R	N/R	5.0
Computer Programming	0	0	0	0	0	0
Computer Science	6.5	11.7	13.4	1.5	3.7	3.4
Computer Science and Engineering	N/R	N/R	16.2	N/R	N/R	3.0
Computer Science Technology	N/R	N/R	15.0	N/R	N/R	0
Computer Technology	0	1.3	0	0	1.0	0
Data Processing	3.3	1.5	9.0	1.0	0	3.0
Information & Computer Science	N/R	1.0	35.0	N/R	13.0	2.5
Information Processing	3.0	0	0	0	0	0
Information Science	7.1	4.9	41.7	.5	1.8	1.3
Information Systems	3.0	4.8	13.5	0	.3	2.6
Other	39.0	0	11.9	15.0	0	1.0
Options in...	9.9	N/R	N/R	7.1	N/R	N/R
Systems Analysis	0	2.0	0	0	0	0
Systems Computer Engineering	N/R	N/R	10.0	N/R	N/R	0
Systems Engineering	15.0	7.1	7.5	2.0	1.4	0
Systems & Information Science	N/R	18.0	3.0	N/R	4.0	2.0
Systems Science	N/R	0	1.0	N/R	0	0
Total	7.7	9.3	14.1	3.5	4.2	2.9

N/R = Not Recorded

ence (7%), and information systems (7%).

The number of doctoral degrees awarded in computer science increased to 82% of all doctoral degrees awarded in 1969-70, but in 1976-77 represented 68% of the total. Other program titles offering a significant number of doctoral degrees in 1976-77 include: computer science and engineering (9%) and information systems (6%).

Productivity of academic graduate programs is best measured by production per program. The above results, based on the "absolute" data reported in the surveys, leave open the question as to how much effect an increase in degree programs has in the change in numbers of degrees awarded. Table 11.8 addresses this issue, and gives, by program name, the reported number of master's degrees awarded divided by the reported number of master's degree programs and the number of doctorates awarded divided by the number of doctoral programs reported. See Tables 11.3 and 11.4 for the reported numbers in all categories.

Productivity of master's degree programs increased significantly over the period, but doctoral programs decreased by 16%.

Staffing

The institutions which reported staffing data were not asked to separate data on faculty for graduate degree programs and undergraduate degree programs. Therefore, it is not meaningful to create additional tables to those already included in the preceding chapter by Gerald Engel (Tables 10.8-10.11). No further discussion of staffing, therefore, is included in this chapter.

Costs of Computer Services

Data on costs of computer services is related to specific courses in the survey. Because the survey did not distinguish graduate and undergraduate enrollments in courses and because most institutions offering graduate degree programs also offer undergraduate degree programs, it is not meaningful to create tables different from those in chapter 10, by Gerald Engel. No additional discussion of those tables is included in this chapter.

Conclusions and Projections

The increase in estimated graduate degree programs is substantial during the period from 1966-67 and 1976-77. Master's degree programs increased by 129% and doctoral programs by 105%. Some growth should continue considering the increases reported both in bachelor's degree programs and enrollments, plus the need for more education to keep current in the field. Much of the increase that occurred between 1966-67 and 1976-77 was due, in large measure, to the events in computer science education in the late 1960s. If the trend in number of graduate programs continues, then both master's and doctoral degrees should show a steady, but slower, rate of increase.

Graduate enrollments increased 85% from 1966-67 to 1969-70, but at the slower rate of 57% from 1969-70 to 1976-77. These trends are consistent with the changes in degree programs and degrees awarded as discussed above.

Computer science is the predominant name used by computer-related degree programs. There has been an increase in the number of programs with information systems- and engineering-oriented titles. Curriculum recommendations were published in 1972,[3] 1973,[4] and 1977[5] in these areas, which could account for the increases. The need and importance of these programs will continue to grow as business-oriented applications grow and if interest in software engineering gains momentum.

There was an increase in the introduction of master's degree programs in all sizes of public institutions, but among private institutions only in those that enroll 2,500-9,999 students. The latter institutions began the only doctoral program introduction. Public institutions which can afford the resources necessary to sustain graduate programs are introducing doctoral programs, most probably to respond to student interest and the needs of the job market.

The increase in graduate enrollments is due, at least in part, to the increase in number of programs. However, the average number of graduate students per program is also increasing (from thirty-two in 1966-67 to forty-two in 1976-77). There are no indications to suggest any change in this trend.

Enrollments are primarily in programs titled computer science. Only one other program title, computer science and engineering, shows more than 5% of the total graduate student enrollment. However, the increase in enrollments in computer engineering and computer science and engineering programs should be noted; it has changed from not being reported separately in 1966-67 to approximately 12% of the total enrollment in 1976-77. This trend should continue, considering the increasing development of software engineering curricula. Programs entitled data processing, information processing, systems analysis, systems engineering, and systems and information science have showed a marked drop in enrollment while the totality of information science-oriented programs has shown little change. An interpretation of survey data on specific courses is given in Chapter 10. Productivity of graduate programs in computing has improved in recent years. There were increases not only in the number of graduate enrollments, degree programs, and degrees awarded from 1969-70 to 1976-77, but also in the number of degrees per graduate student. In 1969-70 approximately one out of every six graduate students received master's degrees; in 1976-77 approximately one out of every four received master's degrees. In the same two years, doctoral degree production was approximately one out of every thirty graduate students.

Survey data related to faculty and to cost of computer services for baccalaureate programs are interpreted in Chapter 10. The same inferences can be made for graduate programs since most faculty teach both graduate and undergraduate courses.

Computer-related programs at the master's and doctoral level are increasing. Enrollments and degrees awarded are also increasing. However, the number of graduate degrees currently awarded does not meet demands. Current hiring practices indicate that educational institutions and industry will have increased needs for computing personnel with graduate degrees. It appears that the demand will continue to exceed the supply if present trends continue. The production of qualified master's and doctoral degree candidates, and the related task of developing appropriate graduate programs to meet future needs, appear to be the most significant problems facing graduate institutions.

Notes

1. W. F. Atchison, and J. W. Hamblen, "Status of Computer Sciences Curricula in Colleges and Universities," *Communications of the ACM* 7 (April 1964):225-27.

2. Curriculum Committee on Computer Science (C^3S), "Curriculum '68, Recommendations for Academic Programs in Computer Science," *Communications of the ACM* 11 (March 1969):151-97.

3. R. Ashenhurst (Ed.), "Curricula Recommendations for Graduate Professional Programs in Information Systems," *Communications of the ACM* 15 (May 1972):363-98.

4. D. J. Couger (Ed.), "Curriculum Recommendations for Undergraduate Programs in Information Systems," *Communications of the ACM* 16 (December 1973):727-49.

5. T. Cain (Ed.), *Model Curriculum in Computer Science and Engineering*, IEEE Computer Society, January 1977.

12

Manpower Training

Orrin E. Taulbee

Historical Perspective

Manpower training in the computer-related programs as defined here includes programs labelled computer science, data processing, information systems, and computer engineering. These cover a broad spectrum—from hardware to software to theory to applications. In order to provide insight into this great diversity, a historical perspective is useful.

In the early years, prior to 1955, training at the college level occurred in what was frequently called the "computing laboratory." There the student, who was most likely a graduate student since the computer was used to support research, learned about the computer in an apprentice-like fashion under the guidance of one of the staff members of the laboratory personnel under the auspices of an academic department, for example, mathematics or electrical engineering. The choice of the department in a particular university usually resulted from the departmental membership of the professor from the laboratory staff offering the course. These early courses were primarily programming courses, but within a few years other courses, for example, on programming languages and interpreters, appeared.

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In some cases graduate students, usually doctoral students working in the laboratory and using the computer as a tool for computation in their own research, redirected their efforts and began computer-related research. They obtained the first degrees in computing under the auspices of the department of the major professor in the computing laboratory. Thus, most early computer-related academic programs occurred at the doctoral level, either as an option in an existing department, or by formation of a program directed by a committee of interested faculty members. The first such program under the direction of a committee was started in 1958 and labelled communication sciences at the University of Michigan. The first program which was called computer science was established in 1961 as a subunit within the Mathematics Department at Stanford University. This program became the Department of Computer Science in 1965. These events heralded a period that lasted until 1972, within which most doctoral programs were founded. Most began as new departments, but in some cases they originated as options within existing departments. In a few cases, degree programs began as interdisciplinary efforts under the direction of a committee. Few, if any, of the doctoral programs that were founded under the direction of an interdisciplinary committee have survived.

In most of the departments with doctoral programs, master's degree programs followed shortly thereafter. A few departments started with master's programs and initiated doctoral programs later.

Some of these graduate departments with established programs announced bachelor's degree programs just after the mid-sixties. This led to much discussion in the academic community about curriculum definition. One such far-reaching effort resulted in the announcement and publication by the Association for Computing Machinery (ACM) of "Curriculum '68" for computer science. Work began on this effort in about 1960. Since 1972, work has been devoted to updating "Curriculum '68," and a revision, "Curriculum '78," was published in the March 1979 issue of *ACM Communications.*

Recognizing the need for programmers, particularly in business applications of the computer, junior (community) colleges in the early 1960s began establishing associate degree programs. These curricula, leading to an associate in science degree, were intended as terminal degree programs. More recently, there has been a shift to the associate in arts degree, indicating not only more emphasis on the liberal arts aspect but also a program which articulates with bachelor's programs. See Chapter 9 for further discussion of the articulation issue.

Since about 1972, many colleges and universities have established a bachelor's level computer-related program either as a new department or as a program in an existing department. Many of these same universities later initiated a master's program. Thus, in the 1970s the establishment of computer-related programs has begun to follow the more traditional pattern in other disciplines of moving from an undergraduate level program to the graduate level. Since 1976, bachelor's level programs have proliferated at a fast pace. Rapid growth has resulted from three factors: the high demand for graduates, the decline in students seeking majors in many other fields due to limited job opportunities, and an attempt by colleges and universities to counteract the prospect of a decline in enrollment due to demographic factors.

Variety of Programs

Given this historical background and the fact that the computer is universal in its application and its effect, it is not surprising that there are not only a large number of computer-related programs but also many different types of programs.

In the 1976-77 inventory of computers, sixteen choices for degree program names were given to the respondents, shown in Table 12.1. Likewise, the thirty organizational locations, i.e., department names for housing the programs are shown in Table 12.2. Table 12.3 shows the distribution of programs at the different degree levels and the departments within which they are located. Here, A indicates the associate degree, B the bachelor's degree, M the master's degree and D the doctorate. From the table, it may be noted that, at the associate level, the data processing program occurs in the largest variety of departments, with the computer science program running a close second. At

Table 12.1
Degree Program Names Offered to Respondents 1976–77

Computer Engineering
Computer Programming
Computer Science
Computer Science Technology
Computer Technology
Computer Science & Engineering
Data Processing
Information Processing
Information and Control Sciences
Information Science
Information Systems
Systems Analysis
Systems Engineering
Systems and Information Sciences
Systems Sciences
Other

the bachelor's, master's, and doctorate level the computer science program occurs in the greatest variety of departments, with the information systems program in each case running second.

At the associate degree level, business administration departments contain the greatest number of different programs with computer science departments the runner up. At the bachelor's level, business administration and electrical engineering departments share first place in the number of different programs with computer science departments a close second. At the master's and doctorate levels, electrical engineering takes first place, while business administration is second at the master's level and business administration and computer science are tied for second at the doctorate level.

Table 12.2
Department Location for Computer—Related Degree Programs 1976-77

Business Administration
Computer and Communications Sciences
Computer and Information Sciences
Computer Programming
Computer Science
Computer Technology
Data Processing
Electrical Engineering
Electrical Engineering Technology
Industrial Engineering
Information and Computer Sciences
Information Processing
Information Science
Information Systems
Mathematics
Systems Analysis
Systems Engineering
Systems and Information Sciences
Systems Science
More than one of the above; Committee
Other Departments in: Engineering
Environmental Sciences
Life Sciences
Mathematical Sciences
Physical Sciences
Social Sciences
Statistics and Computer Science
Education
Business, Commerce
Other Departments not Elsewhere Classified

Table 12.3
Location of Computer-Related Programs by Department and Degree Program 1976-77

Department →

Degree Program	Business Administration	Computer and Communications Sciences	Computer and Information Sciences	Computer Programming	Computer Science	Computer Technology	Data Processing	Electrical Engineering	Electrical Engineering Technology	Industrial Engineering	Information and Computer Sciences	Information Processing	Information Science	Information Systems	Mathematics
Computer Engineering	A M							B M D							
Computer Programming	A		A	A B	A		A							A B	A B
Computer Science	A B	A M	A B M D		A B M D	A	A B	B M D		B M D	B				A B M D
Computer Science Technology		A			A			B	A B	B M					M
Computer Technology	A M				A	A B									
Computer Science & Engineering					B M D			B M D							
Data Processing	A B M D		A	A	A B	A	A B	A						A	A
Information Processing			B									A			
Information and Control Sciences	B		A B M D								A B M D				
Information Science	B				B								A B M D	B	B
Information Systems	B M D		B					B M D		B M D	A B			A B M D	
Systems Analysis	A														
Systems Engineering								M		B					
Systems and Information Sciences										B					
Systems Sciences					M										
Other	A B M D		A B		A B M D	A		B M D	A					B	A B

Table 12.3 Continued

Department → / Degree Program	Systems Analysis	Systems Engineering	Systems and Information Sciences	Systems Science	More than One of the Above: Committee	Other Departments in: Engineering	Environmental Sciences	Life Sciences	Mathematical Sciences	Physical Sciences	Social Sciences	Statistics and Computer Science	Education	Business, Commerce	Other Departments Not Elsewhere Classified
Computer Engineering															
Computer Programming												B M		A	
Computer Science					A B M				A B M D			B M D		A B	A B M D
Computer Science Technology					A B										A
Computer Technology															
Computer Science & Engineering					M										B M D
Data Processing				A	A									A B M	A
Information Processing															
Information and Control Sciences															
Information Science															M
Information Systems					B M									B	B M D
Systems Analysis															
Systems Engineering						M									
Systems and Information Sciences			B M			B M D									
Systems Sciences												B			
Other					B				B M D			B			A B M D

A = associate degree; B = bachelor's degree; M = master's degree; and D = doctorate.

If we assume that the department within which the program is located shapes the character of the program to the extent that it becomes unique, then Table 12.3 indicates that there are at least fifty-five different associate degree, sixty-three bachelor's, forty-two master's, and twenty-seven doctorate programs. Certainly bachelor's level information systems programs located in a business administration department and an electrical engineering department will differ. In other cases, however, the same program, not only in name but in content also, may be located in different departments. In any case, the number sixteen is a lower bound on the number of distinctive programs at all degree levels and the numbers given above represent reasonable upper bounds at the various degree levels. The importance of this discussion is that students who desire a specific type of academic program can surely find the program to fit their needs.

Number of Programs

Table 12.4 shows the estimated number of the different types of programs at the various degree levels. Refer to tables in Chapters 9 and 10 for a comparison with reported numbers of programs. Of the total, more than half of the degree programs at the associate level are data processing. In each case, more than half of the degree programs at the bachelor's, master's, and doctorate levels are computer science.

In Table 12.5 the location of degree programs by institutional level is indicated. Reported figures by institutional level are included in Chapters 9 and 10. In the left-hand column, the word "associate" means that the associate degree is the highest degree awarded by the institution; the indicator "bachelors" is the highest degree awarded by the institution; and so on. From the table it may be noted that 77% of the associate degree programs are located in institutions where that is the highest degree awarded, while very few doctorate level institutions offer that degree. Approximately 15% of the bachelor's programs are located in bachelor's level institutions. From other sources we have indications that the number of such programs may have increased markedly since the 1976-77 date of the fourth inventory of computers in higher education.

Table 12.4
Estimated Number of Degree Programs by Program Name and Level 1976–77

	Degree Program Level			
Type of Degree Program	Associate	Bachelors	Masters	Doctorate
Computer Science	110	290	123	58
Data Processing	320	39	2	0
Computer Programming	62	2	0	0
Information Systems	6	35	12	7
Other	92	140	61	36
Total	590	506	198	101

Table 12.5
Estimated Number of Degree Programs by Institution Level 1976–77

	Degree Programs			
Level of Institution	Associate	Bachelors	Masters	Doctorate
Associate	457	-	-	-
Bachelors	53	75	-	-
Masters	68	227	36	-
Doctorate	12	204	162	101
Total	590	506	198	101

Production of Graduates

Table 12.6 indicates the estimated number of degrees awarded with different majors at the various degree levels. Reported figures for each level are included in Chapters 9 and 10. At the associate level, data processing majors account for 62% of the total. At the bachelor's, master's, and doctorate levels, computer science majors represent 56%, 59%, and 69%, respectively, of the total degrees awarded.

Table 12.6
Estimated Number of Degrees Granted by Program Name 1976–77

Type of Degree Program	Number of Degrees Awarded			
	Associate	Bachelors	Masters	Doctorate
Computer Science	1164	4301	1638	201
Data Processing	5399	573	0	0
Computer Programming	1057	16	0	0
Information Systems	14	488	163	19
Other	1023	2275	968	73
Total	8657	7653	2769	293

Table 12.7
Estimated Average Number of Degrees Awarded per Program

Type of Degree Program	Associate	Bachelors	Masters	Doctorate
Computer Science	10.6	14.8	13.3	3.5
Data Processing	16.9	14.7	--	--
Computer Programming	17.0	8.0	--	--
Information Systems	2.3	13.9	13.6	2.7
Other	11.1	16.2	15.9	2.0
TOTAL	14.7	15.1	14.0	2.9

At the associate, bachelor's, and master's levels, the average number of graduates per program is surprisingly consistent (approximately fifteen) irrespective of the type of program. The exceptions to this were information systems programs at the associate level and computer programming programs at the bachelor's level. As was to be expected, the average number of doctorates awarded was small, roughly three for each program, and this figure seemed to be independent of the type of program.

Table 12.8 indicates the estimated number of degrees awarded by the different level institutions. Refer to Chapters 9 and 10 for reported numbers of degrees. From this table we observe that 90% of associate degrees were awarded by the associate level institutions; 92% of the bachelor's degrees were awarded by the graduate level institutions; and 88% of the master's degrees were accounted for by the doctorate level institutions.

Average productivity of degree programs by institutional level is summarized in Table 12.9. Note that the average number of bachelor's degrees awarded per program in the bachelor's level institutions and the average number of master's degrees awarded by the master's level institutions are both quite small.

Table 12.10 breaks down the estimated numbers of graduates by program names and degree levels for public and private institutions. The sum of the entries in similar positions in the two tables gives the entry in the corresponding position in Table 12.6. Note that the number of associate degrees awarded by the private institutions is quite small—only 6% of the total. The private institutions awarded 19% of the total number of degrees at the bachelor's level, 25% at the master's level, and 24% at the doctoral level.

Quality Indicators

In comparison with the 1969-70 computer inventory, a number of factors indicate greatly improved quality of the graduates in the 1976-77 inventory.

First, the variety of courses is much larger in the typical 1976-77 program. At the associate and bachelor's level there is a much smaller percentage of the courses concerned with programming—even in those programs which are labelled computer programming. Many of the courses now taught at the undergraduate level were previously taught at the graduate level. Instructors have benefited from the much improved variety and quality of textbooks available.

Second, the supply of people trained in computer-related programs was not very large in 1969 as a result of the small number of programs which had been established at that time. Many more were trained in 1976-77. As an indicator of improved

Table 12.8
Estimated Number of Degrees Awarded by Level of Institution 1976–77

	Number of Degrees Awarded			
Level of Institution	Associate	Bachelors	Masters	Doctorate
Associate	7742	-	-	-
Bachelors	362	615	-	-
Masters	361	3259	331	-
Doctorate	192	3779	2438	293
Total	8657	7653	2769	293

Table 12.9
Average Productivity of Estimated Degree Programs by Institutional Level 1976–77

	Average Number of Degrees Awarded per Program at the Different Institutional Levels			
Level of Institution	Associate	Bachelors	Masters	Doctorate
Associate	16.9	-	-	-
Bachelors	6.8	8.2	-	-
Masters	5.3	14.4	9.2	-
Doctorate	16.0	18.5	15.1	2.9
Total	14.7	15.1	14.0	2.9

quality of faculty, note the number of faculty with doctorates in computer science among the institutions offering computer-related degree programs. Detailed figures on the estimated number and proportion of faculty doctorates are included in Table 12.11. It is to be expected that, in the future, the proportion of faculty with doctorates who teach in a computer-related program will increase, and the proportion with doctorates in other fields will decrease.

Third, in 1969 only a very limited number of colleges and

Table 12.10
Estimated Number of Degrees Awarded in Public vs. Private Institutions by Program Name and Degree Level 1976–77

Private Institutions

Type of Degree Program	Estimated Number of Degrees Awarded			
	Associate	Bachelors	Masters	Doctorate
Computer Science	104	957	352	51
Data Processing	114	75	0	0
Computer Programming	161	3	0	0
Information Systems	0	99	47	5
Other	153	302	291	14
Total	532	1436	690	70

Public Institutions

Type of Degree Program	Estimated Number of Degrees Awarded			
	Associate	Bachelors	Masters	Doctorate
Computer Science	1060	3344	1286	194
Data Processing	5285	498	0	0
Computer Programming	896	13	0	0
Information Systems	14	389	116	9
Other	870	1973	677	20
Total	8125	6217	2079	223

universities provided any type of computing service other than batch. By 1976-77, 41% of the institutions provided interactive computing. Also, by this time many departments had acquired one or more laboratory computers so that hands-on experience became a reality for many students. Today, the proliferation of mini- and microcomputers in computer-related departments provides more students the opportunity to gain hands-on experience, not as a replacement for the batch processing experience, but as a supplement.

Table 12.II
Staff in Computer—Related Programs by Program Level

	Staff						
	Total Staff in Programs					Faculty	
Level of Institution	CPR	CSC	DPR	ISY	FTE	Doctorate in CSC	Doctorate in Other Field
Associate	210	212	1616	22	2286	27	47
Bachelors	71	137	50	13	549	45	110
Masters	14	1161	81	95	1561	221	471
Doctorate	7	2195	53	229	3472	812	1179
TOTAL	302	3705	1800	359	7868	1105	1807

Observations and Trends

In the 1976-77 survey, the data showed a relatively small number of bachelor's degrees awarded by the four-year institutions. This situation has changed markedly and will continue to do so as a result of the rapid increase in the number of new degree programs being established in these institutions.

There is an unprecedented growth in numbers of majors due to the high demand for graduates trained in computer-related programs. This demand has continued, stronger each year than the previous one since the year of the current survey. No decrease in demand in the near future is predicted at this time.

There is danger of deterioration in quality of programs. Currently, qualified faculty are in extremely short supply. The multiplicity of job opportunities for bachelor's level graduates is attracting those who might be inclined to continue studying for graduate degrees to accept employment, thus decreasing the pool of potential faculty. This decline in graduate student population does not bode well for many graduate programs since a number of existing ones are marginal in operation due to small enrollment. Moreover, because of the tight financial situation faced by higher education, many individuals choose not to accept academic employment and some of those already there are opting for the nonacademic environment.

Another source of the load placed upon computer-related programs comes from those students majoring in another discipline who want to take one or a few courses. This desire stems from the fact that they are more attractive to an employer, who is hiring them for their expertise in their own discipline, if they have some knowledge of the computer.

Many graduates in other disciplines, having difficulty in finding suitable employment, are returning to colleges or universities for an additional degree in a computer-related program. Others, satisfactorily employed, are seeking a degree in a computer-related program as a means of making a mid-career change.

Colleges and universities have engaged in very little continuing education, that is, updating, for computer-related graduates. This is handled in large part by professional societies, hardware vendors, and other organizations offering a variety of short courses—one day to two weeks—on specialized topics.

Though data were not collected in the 1976-77 inventory on supply-demand, informal professional communication indicates that the greatest imbalance in the supply-demand equation for computer-related specialists occurs in information systems. Production of such specialists is small at all degree levels and is likely to continue in the near future since only a limited number of programs have been established recently.

13

Financing Computing

David Nyman

Introduction

There were several stated purposes for performing the Fourth Inventory of Computing in Higher Education (FICHE). The purposes that apply most directly to this section are:

- To provide data for comparisons between and among institutions.
- To provide a needs assessment at the federal government level.
- To provide an analysis of the recent growth of computing.

To satisfy these purposes, population estimates were made from the institutional data on total expenditures and source of funds. Each of the forty reported elementary data items was multiplied by its extrapolation ratio and the resulting population estimate was summed by different aggregation levels for analysis purposes. Institutional aggregations are reported in this chapter by institu-

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tional control, highest level of degree offering, and enrollment category.

Institutions reported total expenditures of $531,903,000 and total sources of income of $512,646,000. The extrapolated population estimate for the 1976-77 level of support of computing for all institutions was $991,000,000. This estimate was based on reported expenditures and includes an additional 20% above institutional reported expenditures to account for indirect costs. The reader should be aware of certain analytical restrictions that were caused by the definitions used when the data were collected and should see note 1 to ascertain the reporting instructions to the institutions.

First, general state assistance for computing was not reported as a separate category. While the sources of computing support include a state category, institutions were instructed to use this category for reporting special or contractual usage by state agencies. State-assisted institutions reported their regular governmental appropriations under institutional income. Consequently, the total amount of state-generated support is unavailable for analysis in FICHE.

Secondly, the total cost of computing is not represented by this data, since no depreciation costs for purchased equipment are included.

Finally, some caution should be exercised when drawing conclusions based on the aggregation units. Of particular concern are the implications about the need for computing support that might be drawn when reviewing data accumulation based on institutional size and highest degree offered. Institutions falling within the same elementary grouping for these two characteristics could have considerable role and mission differences, resulting in different needs for computing support. For example, an engineering institution may fall into the same grouping as a liberal arts institution. Clearly, different levels of computing support are required to satisfy the missions of these two types of institutions.

With these caveats in place, the remainder of this chapter describes the financing of higher educational computing. This information is presented in a series of percentage distributions.

Actual data supporting these analyses can be found in the FICHE statistical report published by EDUCOM.

Source of Support for Computing

The analysis of the 1969-70 and 1976-77 computing inventory data results in the following general findings.[1]

Total support for computing is:

- larger in magnitude at public institutions than at private institutions, but is roughly proportional to enrollment
- concentrated at a relatively small number of institutions
- greatest at doctorate granting institutions
- distributed fairly evenly on a per student basis

Federal support for computing is:

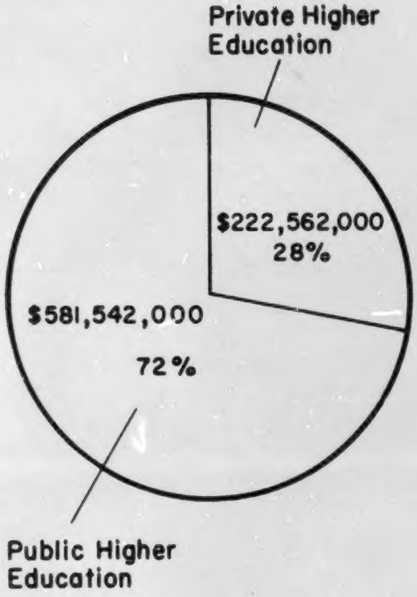
- proportionately less of the total computing support income in 1976 than it was in 1969
- largely concentrated at a few institutions
- concentrated at doctorate granting institutions
- a greater percentage of the total support for computing at the private institutions than at the public institutions

Support by Type of Control

Support for computing in 1976-77 is approximately 2.6 times greater in the public sector than the private sector. Figure 13.1 indicates that of the total support for computing, 72% is within public higher education. This is a slight gain since the 1969 survey, when 68% of the income was within the public sector. The comparable enrollment figures for public sector were approximately 78% in 1976 and 72% in 1969.

The sources of computing support are shown in Figures 13.2 through 13.4. Federal support of computing represents about 7% of the total support. This is decreased from a comparable figure of 17% reported in the 1969 survey. Support from the federal government is approximately 1.4 times greater at the public institutions than at the private institutions. Figures 13.3 and 13.4 indicate that federal support is 10% and 6% of the total computing support at private and public institutions, respectively.

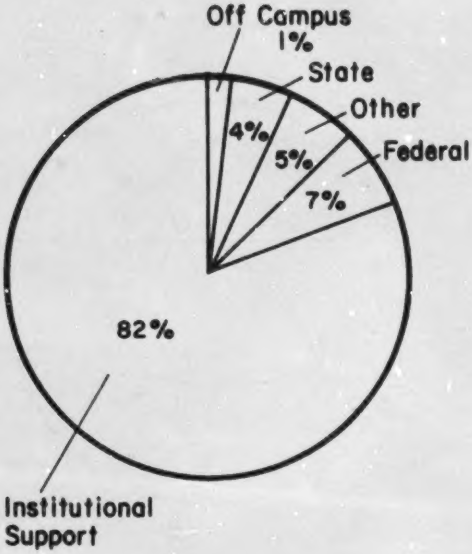
Figure 13.1
Total Computing Support by Sector 1976-1977



This is a substantial decrease from the 1969 survey. In that year, federal support for computing was 24% and 13% of the total support at the private and public institutions, respectively.

Virtually no income for computing at the private institutions comes from state agencies. Nor is income from other off-campus sources large. The two sources of income combined account for less than 1% of total support for private higher education computing. State agency usage accounts for 6% and off-campus income supplies 2% of the support of computing within the public institutions.

Figure 13.2
Higher Education Computing Support by Source of Funds 1976-1977

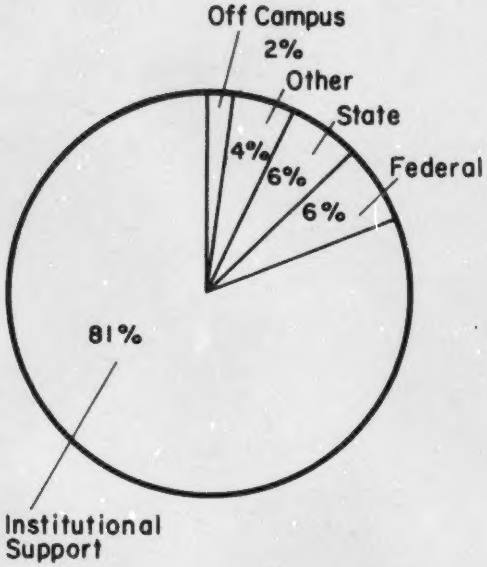


Support by Highest Level of Offering

Support for computing is clearly the greatest at institutions whose highest degree offered is the doctorate.[2] This is evidenced by any of the three measures; percent of total support for computing; support per institution, or support per student, shown in Figures 13.3 through 13.4. Associate degree institutions rank second in percentage of the total support for computing, but, because they serve many students (over four million in 1975), they rank last in computing support per student.

Federal support is also the greatest at doctoral degree grant-

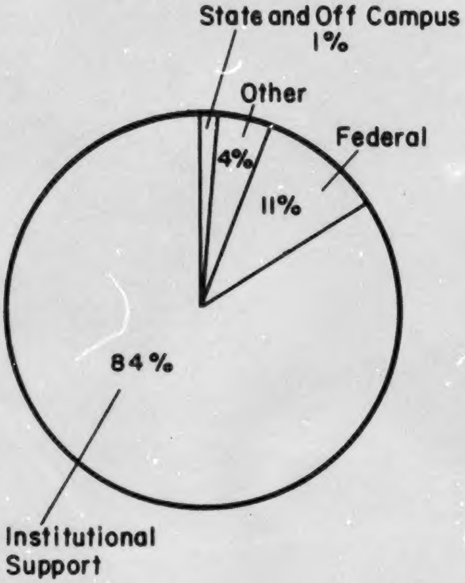
Figure 13.3
Public Higher Education Computing Support by Source of Funds 1976-1977



ing institutions. As indicated in Figure 13.8, 87% of federal support for computing goes to institutions that grant the doctorate degree.

Figure 13.9 shows the effect of the decreasing federal support for computing. Federal support as a percentage of the total support for computing has decreased at each type of degree-granting institution between the 1969 and 1976 surveys. Outside support has also decreased between the two years. The result is an increase in the percentage of institutional support necessary to support the computing activity.

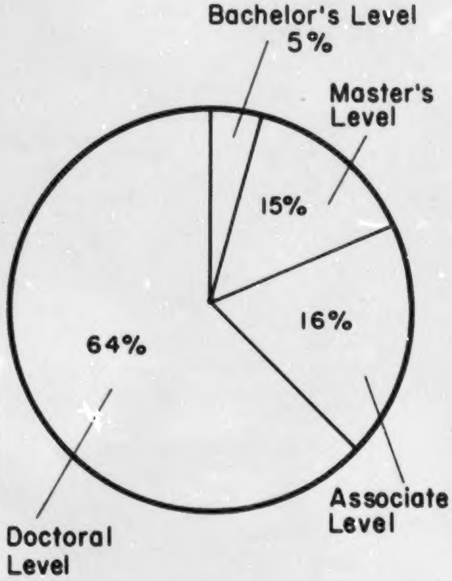
Figure 13.4
Private Higher Education Computing Support by Source of Funds 1976-1977



Support by Institutional Size

Support for computing in higher education is mainly concentrated at a few institutions. As shown in Figure 13.10, approximately 57% of the total support for computing is concentrated at 15% of the institutions. Most (76%) of the computing support is concentrated at 34% of the institutions. An even more concentrated situation is found when federal support is analyzed. Approximately 78% of the total federal support for computing is located at 16% of the institutions in the country. Figure 13.12 displays average federal support per institution on a size and sector comparison. This display indicates the average

Figure 13.5
Percentage of Total Support for Computing by Highest Level of Offering



federal support per institution is largest for private institutions with enrollments greater than 10,000.

Support for computing in higher education is more evenly distributed in terms of support per student in all but the smallest and largest institutions. Eighty-six percent of the total support for computing is located at institutions that enroll eighty-two percent of the students. Total support per student is:

- $2[illegible].00 per student at institutions with less than 500 students
- $74.00 per student at institutions with enrollments between 500 and 2,499 students

Figure 13.6
Computing Expenditures Per Institution Reporting Installations by Highest Level of Degree Offered

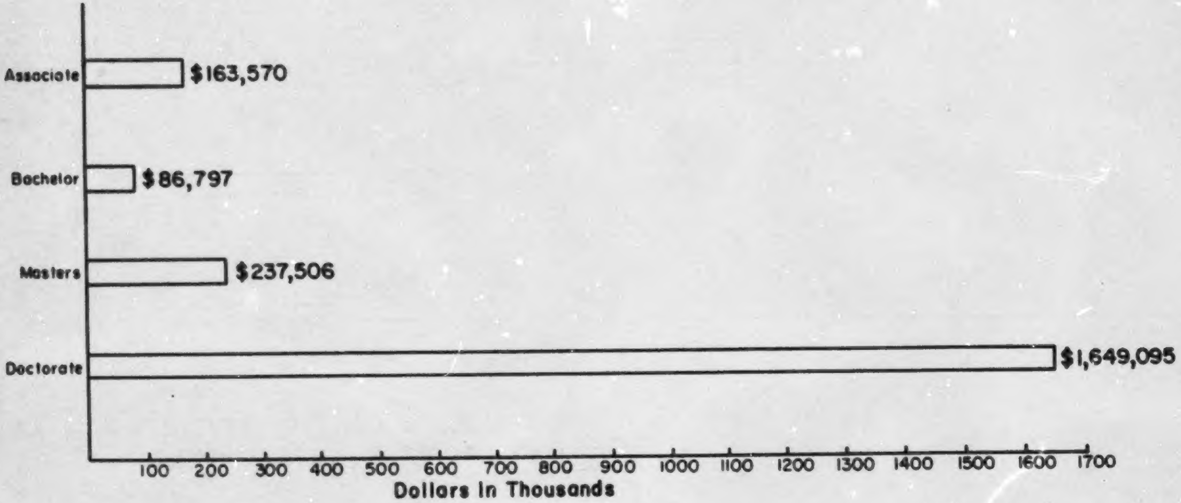


Figure 13.7
Computing Expenditures Per Student
by Highest Level of Degree Offered

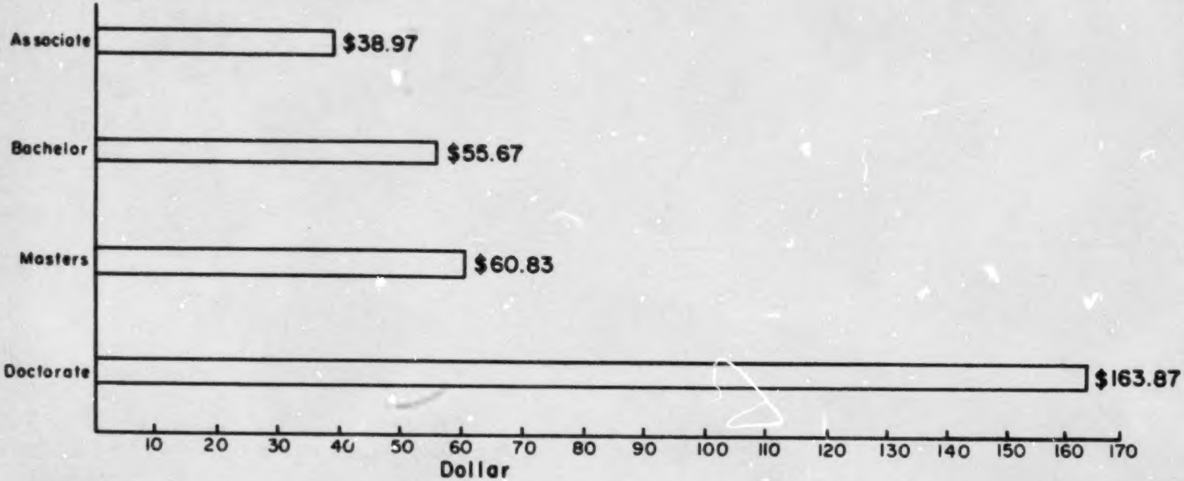
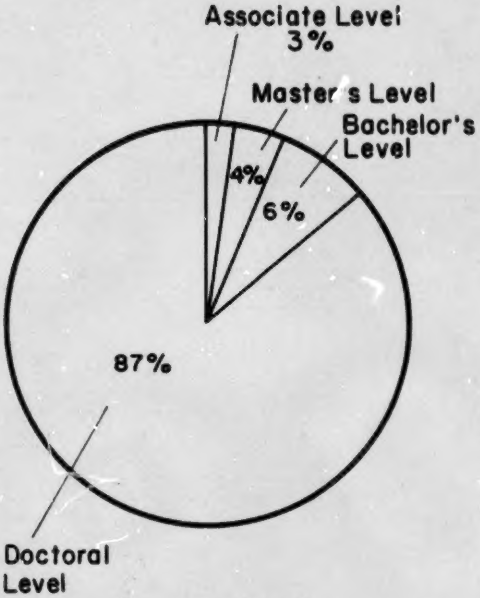


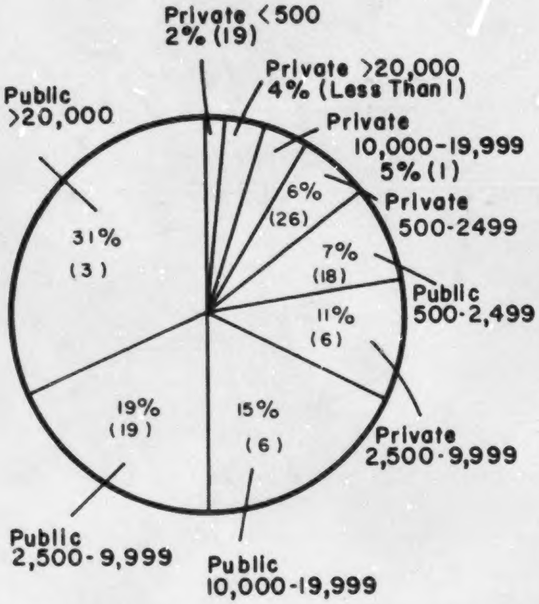
Figure 13.8
Percentage of Federal Support of Computing by Highest Level of Offering



- $81.00 per student at institutions with enrollments between 2,500 and 9,999 students
- $71.00 per student at institutions with enrollment between 10,000 and 19,999 students
- $130.00 per student at institutions with enrollments greater than 20,000

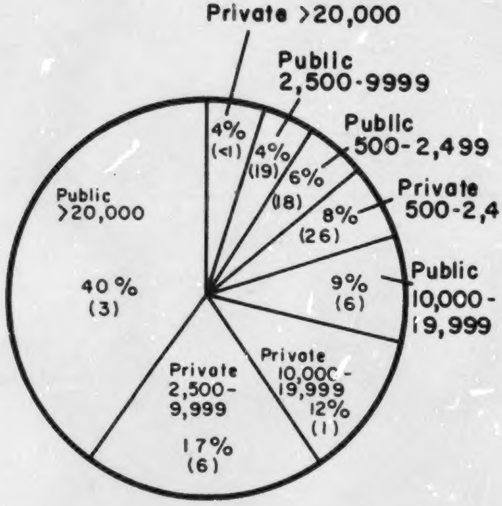
Federal support per student is not as evenly distributed. Figure 13.13 summarizes federal support by institutional size and control. Federal support varies from a low of $0.17 per student at

Figure 13.10
Total Support of Higher Educational Computing by Institutional Size and Sector



Note: Figures in Parentheses Are the % of Total Institutions in That Group.

Figure 13.11
Federal Support of Higher Educational Computing by Institutional Size and Control



Note: Figures in Parentheses are the % of Total Institutions in that Group.

public institutions with less than 500 students to a high of $25.18 at private institutions with enrollments between 10,000 and 19,999.

Expenditures

Analysis of the 1976 and 1969 survey data yield the following general findings:[3]

- In 1976, institutions spent about equal amounts of their combined capital and operating expenditures on hardware and staff.

Figure 13.9

Percentage Comparison of Computing Support by Highest Level of Degree Offered 1969-1970, 1976-1977

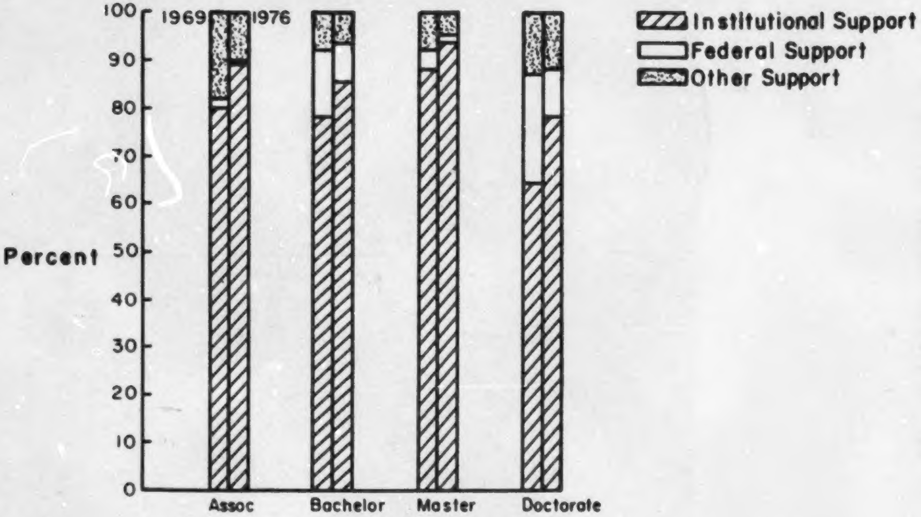


Figure 13.12
Federal Support for Higher Educational Computing in Dollars Per Institution Reporting

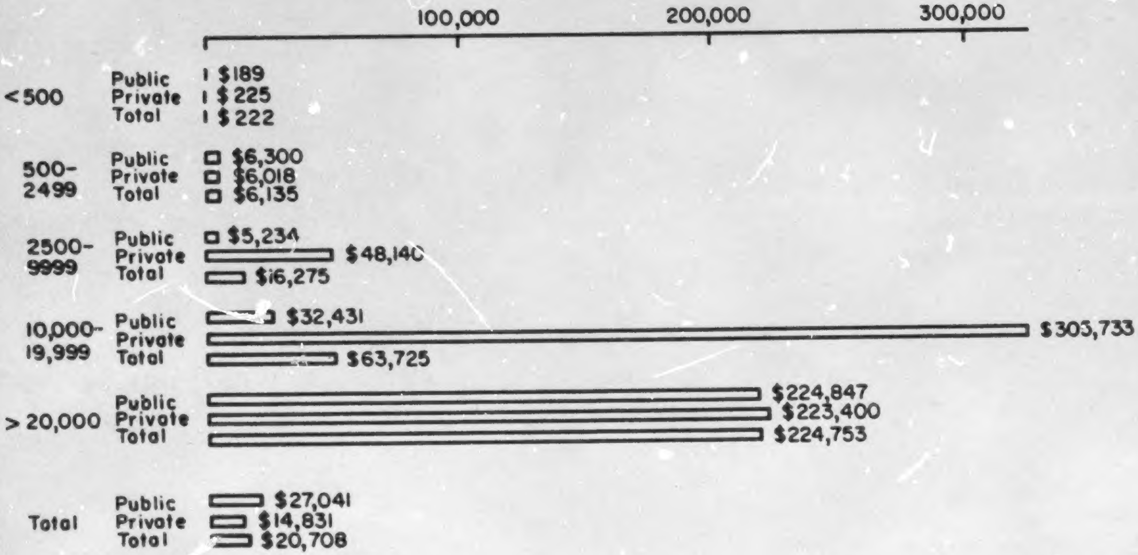
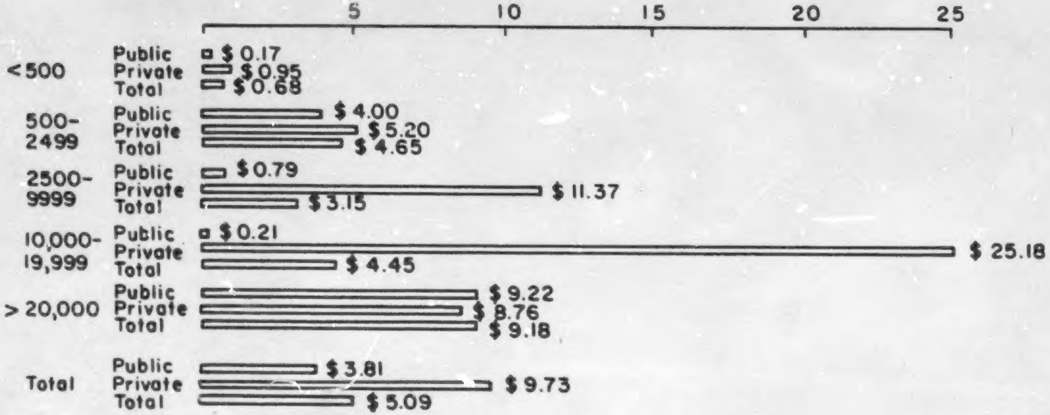


Figure 13.13
Federal Support for Higher Educational Computing in Dollars Per Student



- Hardware expenditures decreased and staff expenditures increased as a percentage of the total combined capital and operating expenditures between 1969 and 1976.
- Capital expenditures for the purchase of equipment increased by almost 200% while operating expenditures for the lease of equipment rose by about 40% between 1969 and 1976.
- On an actual dollar basis, combined capital and operating budget expenditures per student rose from approximately \$58.00 in 1969 to \$74.00 in 1976.
- The combined capital and operating expenditures for all institutions represented about 2.5% of the total 1976-77 education and general expenditures.[4]

Expenditures by Sector

Expenditures for computing at all institutions were about equally divided between hardware and staff. Hardware expenditures were about 40%, and staff expenditures were about 41% of the 1976-77 combined capital and operating budgets. All institutions combined spent about twice as much on staff as on hardware from their operating budgets for computing.

Figure 13.14 displays a percentage breakdown of expenditures by institutional control. Private institutions devoted a greater part of their combined capital and operating budgets for computing to hardware expenditures and less to staff than did public institutions. Private institutions also proportionately spent a greater part of their computing budgets on hardware purchases (23%) than did the public institutions (16%). Proportions expended on other categories were essentially the same between the two sectors of higher education.

Expenditures by Highest Level of Offering

Figure 13.15 displays operating and capital expenditures by highest level of degree offering. This display indicates that all types of institutions spend approximately 40% of their combined computing budgets for hardware. Associate degree level institutions spend proportionately less than other types of institutions for the purchase of hardware.

All but bachelor's degree granting institutions have expanded

Figure 13.14
Percentage of Computing Expenditures by Institutional Control

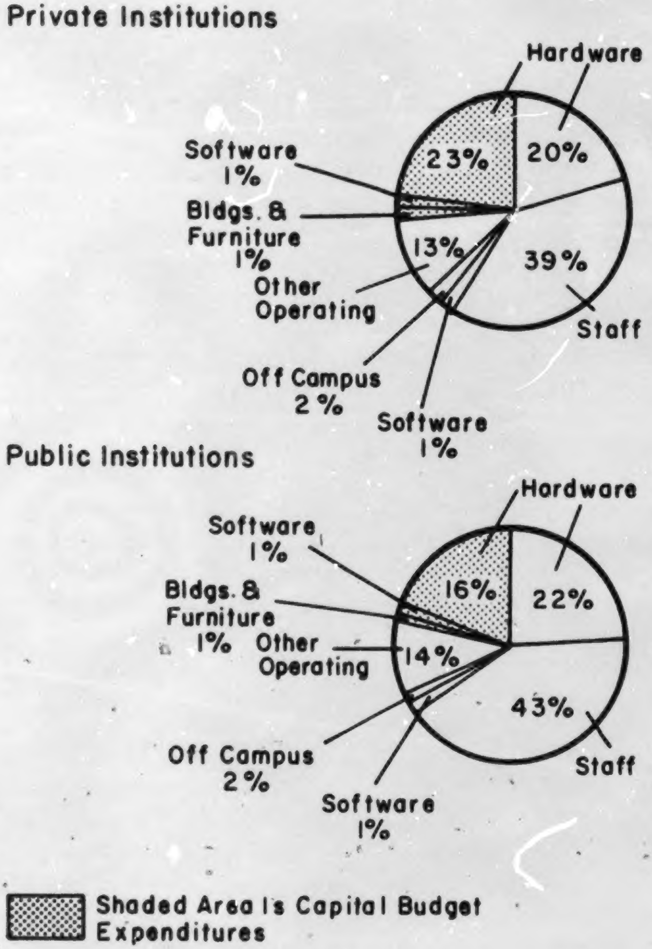
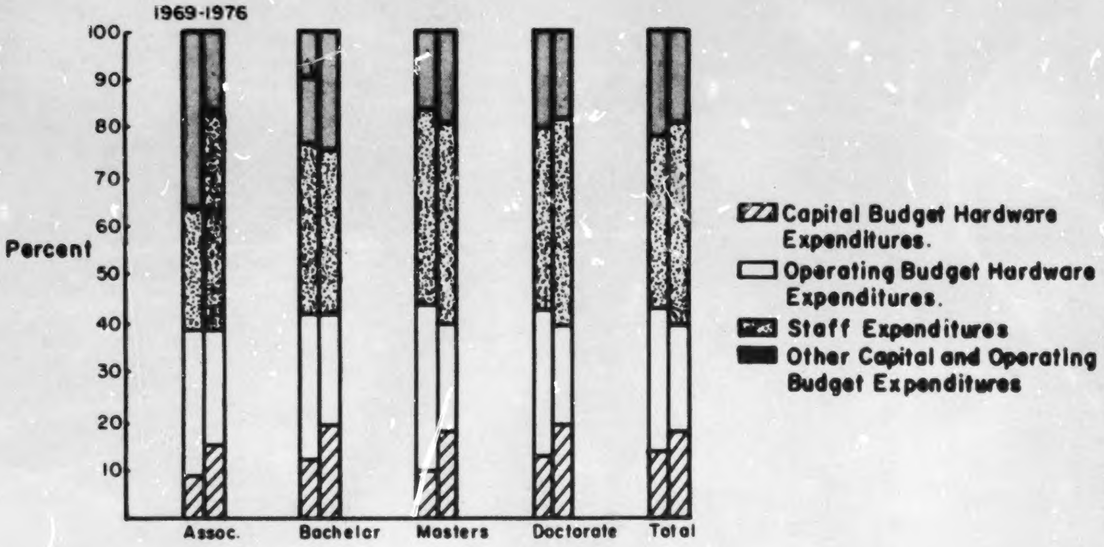


Figure 13.15
Operating and Capital Budget Expenditures by Highest Level of Degree Offered



their proportion of expenditures devoted to staff support between 1969 and 1976. The associate degree institutions have expanded this expenditure the most: from 25% to 44% of their expenditures. Comparison with the expenditures devoted to staff at the other types of institutions in 1969 indicates that associate degree institutions were probably understaffed at that time.

All types of institutions now spend about 80% of their combined capital and operating budgets for hardware and staff. The proportion of the budget is about equally divided between staff and hardware; the largest variance being at the bachelor's level institutions where 42% of the budget is devoted to hardware and 36% of the budget is allocated to staff.

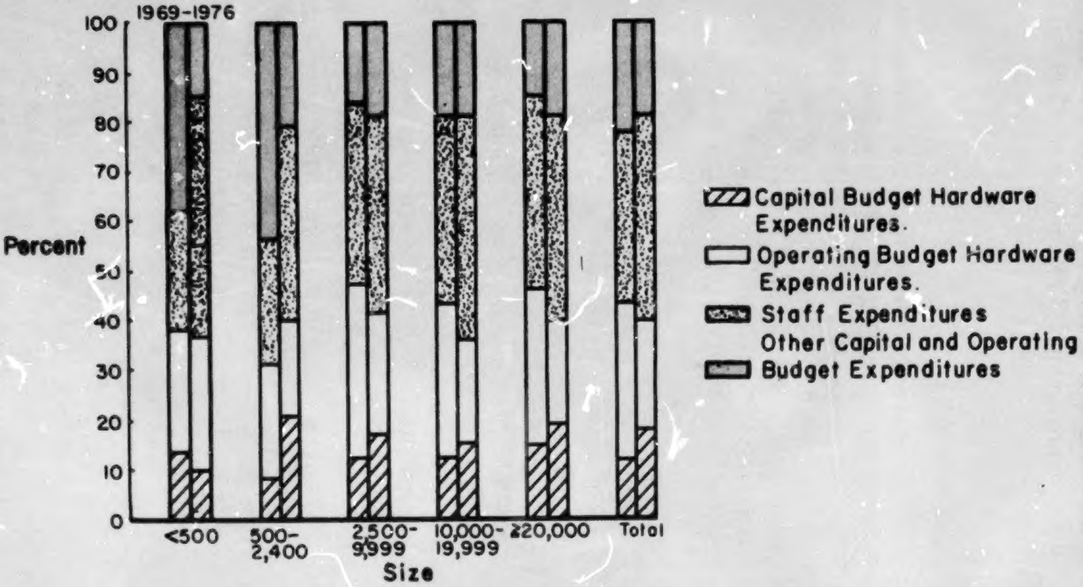
Expenditures by Size of Institution

Figure 13.16 displays operating and capital budget expenditures by size of institution. The combined expenditure for hardware and staff appears to have stabilized at around 80% of the total computing budget at all sizes of institutions. This continues the percentage distribution exhibited in the 1969 survey by institutions with enrollments of greater than 2,500 students. Smaller institutions that had significantly less than 80% of their budgets devoted to hardware and staff in 1969 had achieved this ratio by 1976.

There was a small change in the percentage of the total institutions' budget allocation to hardware and staff between 1969 and 1976. The proportion of the budget devoted to this activity grew from 78% to 81%. However, there was also a change in the component parts of that budget allocation. In 1969, hardware expenditures were 43% and staff were 35% of the total budget. By 1976, the expenditures patterns had changed to the point where staff expenditures were slightly greater than hardware expenditures. In 1976, staff expenditures were 41% and hardware expenditures were 40% of the budget.

In addition, all types of institutions except the smallest (less than 500 students) increased the percentage of their computing budget allocated to the purchase of hardware and decreased the proportion of their hardware lease budget. In total dollars, capital budgets used for the purchase of equipment increased from approximately $60 million to $162 million between the two

Figure 13.16
Operating and Capital Budget Expenditures by Institutional Size



survey years. Operating budgets for computer leases increased from approximately $145 million to $199 million in the same period.

Conclusions

The material presented above is intended to specifically address the three purposes for this section as stated in the introduction. In summary, it can be shown that total financial support for computing has increased from approximately $472 million to over $991 million between 1969 and 1976. However, there is some question about how much of the increase is real. Certainly inflation must have a considerable impact whem comparing the two years. The Consumer Price Index (CPI) stood at 110.2 in July 1969 and at 171.1 in July 1976. The impact of inflation would most probably be felt the most in the staff and supplies expenditures areas. If the CPI is applied, the level of computing support for staff and other expenditures was approximately 40% higher, in terms of constant dollars, in 1976 than in 1969. However, when the increased number of students between the two years are factored into the analysis, the average total computing expenditures per student, in constant 1969 dollars, may actually be less in 1976 than in 1969.

As interesting as the possible effects of inflation might be, these comparisons alone are not an accurate reflection of what is occurring within the computing industry. Computing-related prices between the two years probably have reacted differently than the overall Consumer Price Index. More importantly, no factor for the increase in computing power per dollar is included in price index comparisons.

The amount of computing capability that one dollar purchased in 1976 was significantly greater than that purchased in 1969. To truly determine the difference in support between the two years, some factor for the increase in computing power should be included in the analysis. Since these analyses were not performed, no hard-and-fast conclusion should be drawn. But, based on magnitude of differences in constant dollars exhibited between the two years and on the significant increase in the computing power-cost ratio, a tentative conclusion can be reached that the real support for computing has probably increased between 1969 and 1976.

While total computing support has probably increased, computing support has remained unequally distributed among institutions of higher education. As exhibited in the 1969 survey, the 1976 data indicate significant differences in total and federal computing support. Data for all three control variables—institutional control, size, and highest degrees offered—exhibit some differences among institutions. Only the proportion of expenditures by hardware, staff, and other expenditures offer some degree of consistency across institutions.

Notes

1. All 1976-77 information in this subsection is based on Line 04, FORM No. 1 of the FICHE survey. Summaries of that data appear in *Fourth Inventory of Computing in Higher Education: Statistical Report 1976-77* (Princeton, N.J.: EDUCOM). All 1969-70 comparative data is derived from Table III-1 in: *Inventory of Computers in U.S. Higher Education 1969-70* (Washington, D.C., 20402: U.S. Government Printing Office), Stock No. 3800 0114.

2. This is to be expected because of the large research usage.

3. All 1976-77 information in this subsection is based on Line 03, FORM No. 1 of the FICHE survey. All 1969-70 comparative data is derived by extrapolating the survey information presented in Section VI in: *Inventory of Computers in U.S. Higher Education 1969-70* (Washington, D.C., 20402: U.S. Government Printing Office), Stock No. 3800-1114.

4. The 1977 Fiscal Year Education and General Expenditures were reported as $33,416,591,000 in the April 2, 1979, issue of *The Chronicle of Higher Education.*

APPENDIX A

Institutions Reporting Computer-Related Degree Programs as of June 30, 1971

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
ALABAMA												
Alabama Agricultural and Mechanical College												
Computer Science Program in Dept. of Computer Science		X				X				X		
Auburn University, Main Campus												
Computer Science Program in Dept. of Electrical Engineering						X	X	X		X	X	X
Computer Science Program in Dept. of Industrial Engineering		X	X			X	X			X	X	
Data Processing Program in Dept. of Business Administration						X				X		
Enterprise State Junior College												
Computer Programming Program in Dept. of Business	X				X				X			
Gadsden State Junior College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Jefferson State Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
John C. Calhoun State Technical Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Livingston University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Lurleen B. Wallace State Junior College												
Data Processing Program in Dept. of Data Processing					X				X			
Phoenix College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Alabama, Main Campus												
Computer Science Program in Dept. of Computer Science										X		
ALASKA												
University of Alaska												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Information Systems Program in Dept. of Business Administration									X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
ARIZONA												
Arizona State University												
Computer Science Program in Dept. of Electrical Engineering			X	X			X	X			X	X
Computer Science Program in Dept. of Industrial Engineering		X	X	X		X	X	X		X	X	X
Information Science Program in Dept. of Other		X		X		X		X		X		X
Arizona Western College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Glendale Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Maricopa College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Mesa Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Northern Arizona University												
Data Processing Program in Dept. of Business Administration		X				X				X		
University of Arizona												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
ARKANSAS												
Phillips County Community College												
Data Processing Program In Dept. of Data Processing	X				X				X			
University of Arkansas, Main Campus												
Computer Science Program in Several Departments			X				X				X	
CALIFORNIA												
American River College, Main Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			
Cabrillo College												
Computer Programming Program in Dept. of Engineering	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
California Institute of Technology Information Science Program in Dept. of Engineering			X	X			X	X			X	X
California State College, Los Angeles Information Systems Program in Dept. of Business Administration		X				X				X		
California State Poly College, Pomona Data Processing Program in Dept. of Data Processing		X				X				X		
California State Poly College, San Luis Obispo Computer Science Program in Dept. of Computer Science		X				X				X		
Cerritos College Computer Programming Program in Dept. of Data Processing	X				X				X			
Chabot College Data Processing Program in Dept. of Data Processing	X				X				X			
Citrus College Data Processing Program In Dept. of Data Processing	X				X				X			
College of Alameda Computer Programming Program in Dept. of Business Administration					X				X			
Contra Costa College Data Processing Program In Dept. of Data Processing	X				X				X			
Cosumnes River College Data Processing Program In Dept. of Business Administration									X			
De Anza College Data Processing Program in Dept. of Data Processing	X				X				X			
Diablo Valley College Computer Programming Program in Dept. of Computer Science	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
El Camino College Data Processing Program in Dept. of Data Processing	X				X				X			
Fullerton Junior College Data Processing Program in Dept. of Data Processing	X				X				X			
Grossmont College Data Processing Program in Dept. of Data Processing	X				X				X			
Imperial Valley College Computer Technology Program in Dept. of Business	X				X				X			
Los Angeles Pierce College Data Processing Program In Dept. of Business Administration	X				X				X			
Los Angeles Valley College Computer Technology Program in Dept. of Mathematics	X				X				X			
Data Processing Program in Dept. of Business Administration	X				X				X			
Loyola University of Los Angeles Computer Science Program In Dept. of Electrical Engineering											X	X
Menlo School and College Computer Science Program in Dept. of Computer Science					X				X			
Merced College Data Processing Program In Dept. of Business	X				X				X			
Moorpark Junior College Data Processing Program in Dept. of Data Processing	X				X				X			
Ohlone College Computer Programming Program in Dept. of Data Processing	X				X				X			
Orange Coast College Information Systems Program In Dept. of Information Systems	X				X				X			
Pasadena City College Computer Science Program in Dept. of Computer Science	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Riverside City College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Sacramento City College												
Data Processing Program In Dept. of Data Processing	X				X				X			
San Diego State College												
Information Systems Program in Dept. of Business Administration		X	X			X	X			X	X	
San Francisco State College												
Computer Science Program In Dept. of Mathematics		X				X				X		
San Joaquin Delta College												
Data Processing Program In Dept. of Data Processing	X				X				X			
Santa Ana College												
Computer Science Program in Dept. of Computer and Information Science	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			
Santa Barbara Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Stanford University												
Computer Science Program In Dept. of Computer Science			X	X			X	X			X	X
Computer Science Program in Dept. of Electrical Engineering			X	X			X	X			X	X
United States Naval Postgraduate School												
Computer Science Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
Computer Science Program in Dept. of Mathematics			X				X				X	
University of California, Berkeley												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Mathematics		X	X	X		X	X	X		X	X	X
Information Science Program in Dept. of Business Administration				X			X	X			X	X

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
University of California, Davis												
Computer Science Program in Dept. of Engineering				X				X				X
University of California, Irvine												
Computer Science Program in Dept. of Information and Computer Science		X		X		X		X		X		X
University of California, Los Angeles												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
University of California, Santa Barbara												
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
University of California, Santa Cruz												
Computer Science Program in Dept. of Information and Computer Science		X				X				X	X	X
University of Redlands												
Computer Science Program in Dept. of Computer Science										X		
University of San Francisco												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Southern California												
Computer Science Program in Several Departments			X	X			X	X			X	X
Victor Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
West Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
COLORADO												
Colorado State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Community College of Denver												
Data Processing Program in Dept. of Business	X				X				X			
El Paso Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	H	D
Otero Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Southern Colorado State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Trinidad State Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Colorado, Main Campus												
Computer Science Program in Dept. of Computer Science			X				X				X	X
University of Denver												
Computer Science Program in Dept. of Mathematics		X				X				X		
CONNECTICUT												
Bridgeport Engineering Institute												
Computer Science Program in Dept. of Mathematical Sciences	X				X				X			
Greater Hartford Community College												
Data Processing Program in Dept. of Business					X				X			
Manchester Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Norwalk Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Norwalk State Technical College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Quinnipiac College												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
Rensselaer Polytechnic Institute, Connecticut												
Information and Computer Science Program in Dept. of Information and Computer Science			X				X				X	
University of Connecticut, Main Campus												
Computer Science Program in Dept. of Electrical Engineering			X	X		X	X	X		X	X	X

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	H	D
Yale University												
Computer Science Program in Dept. of Computer Science												X
DELAWARE												
Delaware Technical and Community College, Northern Branch												
Data Processing Program in Dept. of Data Processing	X				X				X			
Delaware Technical and Community College, Southern Branch												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Delaware												
Computer Science Program in Dept. of Computer Science	X	X	X	X	X	X	X	X	X	X	X	X
DISTRICT OF COLUMBIA												
American University												
Computer Science Program in Dept. of Mathematical Sciences									X			
Information Science Program in Dept. of Other							X				[illegible]	
Federal City College												
Computer Programming Program in Dept. of Business Administration						X				X		
Computer Science Program in Dept. of Computer Science						X				X		
FLORIDA												
Brevard Community College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Broward Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Chipola Junior College												
Data Processing Program in Dept. of Data Processing					X				X			
Daytona Beach Junior College												
Computer Science Program in Dept. of Computer Science					X				X			

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	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Edison Junior College												
Data Processing Program in Dept. of Business	X				X				X			
Florida Agricultural and Mechanical University												
Computer Technology Program in Dept. of Computer Science	X	X			X	X			X	X		
Florida Atlantic University												
Information Systems Program in Dept. of Systems Science		X				X				X		
Florida Institute of Technology												
Computer Science Program in Dept. of Mathematical Science		X				X				X	X	
Florida Junior College, Jacksonville												
Data Processing Program in Dept. of Business	X				X				X			
Florida Keys Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Florida Technological University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Fort Lauderdale University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Gulf Coast Junior College												
Data Processing Program in Dept. of Data Processing					X							
Manatee Junior College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Miami-Dade Junior College												
Data Processing Program in Dept. of Computer Programming	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			
North Florida Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Okaloosa Walton Junior College												
Data Processing Program in Dept. of Business	X					X			X			

INSTITUTIONS REPORTING COMPUTER RELATED
DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Pensacola Junior College												
Computer Science Program in Dept. of Data Processing	X				X				X			
St. John's River Junior College												
Data Processing Program in Dept. of Other	X				X				X			
St. Petersburg Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Santa Fe Junior College												
Data Processing Program in Dept. of Business					X				X			
Seminole Junior College												
Data Processing Program in Dept. of Other	X				X				X			
Tallahassee Junior College												
Data Processing Program in Dept. of Data Processing					X				X			
University of Miami												
Systems Analysis Program in Dept. of Industrial Engineering		X	X			X	X			X	X	
University of South Florida												
Systems Engineering Program in Dept. of Systems Engineering		X	X			X	X			X	X	
Systems Analysis Program in Dept. of Business Administration			X				X				X	
University of West Florida												
Systems Science Program in Dept. of Systems Sciences		X				X				X		
Valencia Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
GEORGIA												
Abraham Baldwin Agricultural College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Georgia Institute of Technology												
Computer Science Program in Dept. of Information and Computer Science			X	X			X	X			X	X
Information Science Program in Dept. of Information and Computer Science			X	X			X	X			X	X
Information Systems Program in Dept. of Information and Computer Science			X	X			X	X			X	X

INSTITUTIONS REPORTING COMPUTER RELATED
DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Georgia State University												
Information Systems Program in Dept. of Information Systems			X				X				X	
Middle Georgia College												
Data Processing Program in Dept. of Business Administration	X				X				X			
GUAM												
University of Guam												
Information Systems Program in Dept. of Business Administration	X				X				X			
HAWAII												
Leeward Community College												
Computer Science Program in Dept. of Mathematical Sciences	X				X				X			
University of Hawaii												
Information Science Program in Dept. of Information and Computer Science			X				X				X	
University of Hawaii, Kapiolani Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
ILLINOIS												
Belleville Area College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Black Hawk College												
Computer Programming Program in Dept. of Engineering	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			
Bradley University												
Computer Science Program in Dept. of Computer Science			X				X			X	X	
Carl Sandburg College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Chicago City College, Amudsen- Mayfair												
Computer Science Program in Dept. of Business Administration	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED
DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Chicago City College, Loop Campus												
Data Processing Program in Dept of Data Processing	X				X				X			
College of DuPage												
Computer Programming Program in Dept. of Data Processing	X				X				X			
College of Lake County												
Data Processing Program in Dept. of Data Processing	X				X				X			
Danville Junior College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Devry Institute of Technology												
Computer Technology Program in Dept. of Computer Science	X	X			X	X			X	X		
Eastern Illinois University												
Information Systems Program in Dept. of Business Administration						X				X		
Elgin Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Highland Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Illinois Institute of Technology												
Information Science Program in Dept. of Information Science			X				X				X	
Illinois Valley Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Joliet Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Kas Kasia College												
Data Processing Program in Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Kishwaukee College												
Data Processing Program in Dept. of Data Processing	X				X							
Knox College												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Lakeland College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
McHenry County Jr. College												
Data Processing Program in Dept. of Business	X				X				X			
Moraine Valley Community College												
Data Processing Program in Dept. of Other	X				X				X			
Morton College												
Data Processing Program in Dept. of Business	X				X				X			
Northwestern University												
Computer Science Program in Dept. of Computer Science			X	X			X	X		X	X	X
Parkland College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Prairie State College												
Computer Programming Program in Dept. of Computer Technology	X				X				X			
Rock Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Roosevelt University												
Computer Technology Program In Dept. of Computer Technology	X	X			X	X			X	X		
Sauk Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Southern Illinois University, Main Campus												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Computer Science Program In Dept. of Computer Science							X				X	
Spoon River College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Triton College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Chicago												
Information Science Program in Dept. of Information Science			X	X			X	X			X	X
University of Illinois at Urbana												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Systems Engineering Program in Dept. of Engineering			X	X			X	X			X	X
University of Illinois, Chicago Circle												
Computer Science Program in Dept. of Engineering		X	X			X	X			X	X	
Computer Science Program in Dept. of Mathematics						X				X	X	
Waubonsee Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Western Illinois University												
Information Science Program in Dept. of Information Science						X				X		
Unknown (Palatine Ill.)												
Data Processing Program in Dept. of Business	X				X				X			
INDIANA												
Ball State University												
Computer Science Program in Dept. of Mathematical Sciences		X				X	X			X	X	
Evansville University												
Data Processing Program In Dept. of Information and Computer Science	X				X	X			X	X		

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Indiana Institute of Technology												
Computer Science Program in Dept. of Mathematics		X				X				X		
Indiana University at Bloomington												
Computer Science Program in Dept. of Computer Science										X	X	
Information Systems Program in Dept. of Business							X				X	
Indiana University at Indianapolis												
Computer Technology Program in Dept. of Computer Technology	X	X			X	X			X	X		
Purdue University, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Purdue University, Calumet Campus												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Information Science Program in Dept. of Engineering						X	X			X	X	
Purdue University, North Central Campus												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
St. Joseph College, Main Campus												
Computer Science Program in Dept. of Computer Science						X				X		
Taylor University												
Computer Science Program in Dept. of Computer Science										X		
Tri State College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Vincennes University												
Computer Programming Program in Dept. of Data Processing	X				X				X			
IOWA												
Clarke College												
Computer Science Program in Dept. of Computer Science											X	

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Des Moines Area Community College--Ankeny												
Data Processing Program in Dept. of Data Processing					X				X			
Iowa State University of Science and Technology												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Kirkwood Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
University of Iowa												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
KANSAS												
Barton County Community Junior College												
Data Processing Program in Dept. of Data Processing					X				X			
Butler County Community Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Fort Hays Kansas State College												
Data Processing Program in Dept. of Business Administration		X				X				X		
Kansas City Kansas Community Junior College												
Data Processing Program In Dept. of Business Administration	X				X				X			
Kansas State College Pittsburg												
Data Processing Program in Dept. of Business Administration		X				X				X		
Kansas State Teachers College Emporia												
Data Processing Program In Dept. of Business		X	X			X	X			X	X	
Kansas State University												
Computer Science Program in Dept. of Other		X	X			X	X			X	X	X
Kansas Technical Institute												
Computer Science Program in Dept. of Computer Technology	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
KENTUCKY												
Community College Systems University of Kentucky												
Data Processing Program In Dept. of Data Processing	X				X				X			
Jefferson Community College												
Data Processing Program in Dept. of Data Processing	X											
Morehead State University												
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Murray State University												
Computer Science Program in Dept. of Computer Science										X		
Paducah Community College												
Computer Technology Program in Dept. of Data Processing	X				X				X			
Transylvania University												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Kentucky												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Kentucky Community College System												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Louisville												
Computer Science Program in Dept. of Other						X	X			X	X	
LOUISIANA												
Delgado College												
Data Processing Program In Dept. of Data Processing	X				X				X			
Louisiana Tech University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Data Processing Program in Dept. of Business		X	X			X	X	X		X	X	X
Information Systems Program in Dept. of Engineering		X	X			X	X	X		X	X	X
Nicholls State University												
Computer Science Program in Dept. of Computer Science		X				X			X	X		

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Northwest Louisiana University												
Computer Science Program in Dept. of Mathematics		X				X				X		
Southern University												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Southwestern Louisiana												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
MAINE												
University of Maine, Orono												
Systems Engineering in Dept. of Engineering			X				X				X	
MARYLAND												
Allegany Community College												
Data Processing Program in Dept. of Data Processing									X			
Ann Arundel Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Catonsville Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Charles County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Community College of Baltimore												
Data Processing Program in Dept. of Data Processing	X				X				X			
Hagerstown Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Harford Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Johns Hopkins University												
Computer Science Program in Dept. of Computer Science				X				[illegible]			X	X

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Montgomery College, Rockville												
Computer Science Program in Dept. of Other	X				X				X			
Montgomery College, Takoma Park												
Computer Science Program in Several Depts.	X				X				X			
Prince George's Community College												
Data Processing Program in Dept. of Computer Technology	X				X				X			
University of Maryland, Main Campus												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
MASSASSACHUSETTS												
Boston University												
Data Processing Program in Dept. of Computer Science		X				X				X		
Systems Engineering Program in Dept. of Systems Engineering		X	X			X	X			X	X	
Howard University												
Information Systems Program in Dept. of Business Administration				X				X				X
Holyoke Community College												
Data Processing Program in Dept. of Computer Technology	X				X				X			
Lowell Technological Institute												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Massassachusetts Institute of Technology												
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Mt. Wachusett Community College												
Data Processing Program in Dept. of Business	X				X				X			
Newton Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Northampton Junior College												
Information Systems Program in Dept. of Business Administration					X				X			
Quinsigamond Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
University of Massassachusetts, Amhurst Campus												
Computer Science Program in Dept. of Computer Science			X				X				X	X
Worcester Junior College												
Data Processing Program in Several Departments	X				X				X			
Worcester Polytechnic Institute												
Computer Science Program in Dept. of Computer Science			X			X	X			X	X	
Computer Technology Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
MICHIGAN												
Central Michigan University												
Computer Science Program in Dept. of Computer Science										X		
Delta College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Genesee Community College												
Data Processing Program in Dept. of Business	X				X				X			
Lansing Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Macomb County Community College, South Campus												
Data Processing Program in Dept. of Business	X				X				X			
Michigan State University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Muskegon Business College												
Data Processing Program In Dept. of Data Processing	X				X				X			
Muskegon Community College												
Data Processing Program in Dept. of Business	X				X				X			
Northwestern Michigan College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Oakland University												
Systems Engineering Program in Dept. of Engineering		X	X			X	X	X		X	X	

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Schoolcraft College												
Data Processing Program in Dept. of Business	X				X				X			
University of Michigan, Main Campus												
Computer Science Program in Dept. of Computer and Communication Science		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Mathematics			X	X			X	X			X	X
Systems Analysis Program in Dept. of Other			X				X	X			X	X
University of Michigan, Dearborn												
Computer Technology Program in Dept. of Electrical Engineering			X				X					
Washtenaw Community College												
Data Processing Program In Dept. of Business	X				X				X			
Wayne State University												
Computer Science Program in Dept. of Mathematics						X				X		
MINNESOTA												
College of St. Thomas												
Information Science Program in Dept. of Other		X				X				X		
Mankato State College												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Minnesota, Minneapolis, St. Paul												
Information and Computer Science Program in Dept. of Information and Computer Science						X	X	X		X	X	X
Information Systems Program in Dept. of Business Administration			X	X			X	X			X	X
MISSISSIPPI												
Holmes Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mississippi Gulf Coast Junior College, Jefferson Davis Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mississippi Gulf Coast Junior College, Perkinston Campus												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Mississippi State University												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Monroe County Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Northwest Mississippi Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Southwest Mississippi Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Southern Mississippi												
Computer Science Program in Dept. of Computer Science		X				X				X	X	
MISSOURI												
Central Missouri State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Data Processing Program in Dept. of Business Administration										X		
Central Technical Institute												
Computer Programming Program in Dept. of Engineering	X											
Florissant Valley Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Lindenwood College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Meramec Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Missouri Southern College												
Computer Programming Program in Dept. of Computer Science	X				X				X			
Moberly Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Penn Valley Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
School of the Ozarks												
Computer Science Program in Dept. of Mathematical Sciences										X		

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Southeast Missouri State College												
Computer Science Program in Dept. of Data Processing	X				X				X			
University of Missouri, Columbia												
Computer Science Program in Dept. of Computer Science			X				X				X	
Systems Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Systems Engineering Programs in Dept. of Engineering			X	X			X	X			X	X
University of Missouri, Rolla												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Washington University												
Computer Science Program in Several Depts.		X	X	X		X	X	X		X	X	X
Computer Technology Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
William Woods College												
Computer Programming Program in Dept. of Mathematics		X				X				X		
MONTANA												
Flathead Valley Community College												
Data Processing Program in Dept. of Data Processing	X											
University of Montana												
Computer Science Program in Dept. of Computer Science						X				X		
NEBRASKA												
University of Nebraska, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
NEVADA												
University of Nevada, Reno												
Computer Science Program in Several Depts.											X	
Data Processing Program in Dept. of Information Systems					X	X			X	X		
NEW HAMPSHIRE												
New Hampshire Technical Institute Concord												
Data Processing Program in Dept. of Data Processing	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
University of New Hampshire												
Computer Science Program in Dept. of Mathematics										X		
NEW JERSEY												
Brookdale Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Burlington County College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Cumberland County College												
Data Processing Program in Dept. of Data Processing					X				X			
Essex County College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Farleigh-Dickinson, Madison Campus												
Computer Science Program in Several Depts.										X	X	
Glassboro State College												
Information Systems Program in Dept. of Education		X				X				X		
Mercer County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Middlesex County College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Newark College of Engineering												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Ocean County College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Princeton University												
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Rutgers University, New Brunswick												
Computer Science Program in Dept. of Computer Science		X	X		X	X	X			X	X	X

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	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Stevens Institute of Technology												
Computer Science Program in Several Depts.			X	X			X	X			X	X
Trenton State College												
Computer Science Program in Dept. of Mathematics						X				X		
NEW MEXICO												
Eastern New Mexico University, Main Campus												
Computer Science Program in Dept. of Computer Science						X				X		
Data Processing Program in Dept. of Data Processing	X	X	X		X	X	X		X	X	X	
New Mexico Highlands University												
Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
New Mexico Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
New Mexico Institute of Mining and Technology												
Computer Science Program in Dept. of Computer Science		X				X				X		
New Mexico State University, Main Campus												
Computer Science Program in Dept. of Computer Science			X				X			X	X	
Data Processing Program in Dept. of Business Administration	X				X				X	X		
University of New Mexico												
Computer Science Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
Computer Science Program in Dept. of Mathematics			X				X				X	
NEW YORK												
Auburn Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Community College of the Finger Lakes												
Data Processing Program in Dept. of Data Processing									X			
Cornell University, Main Campus												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
Corning Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
CUNY City College												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
CUNY Graduate Center												
Computer Technology Program in Dept. of Education				X				X				X
CUNY Queens College												
Computer Science Program in Dept. of Computer Science						X				X	X	
Dutchess Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Elmira College												
Systems Analysis Program in Dept. of Other	X	X			X	X			X	X		
Erie Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Fulton Montgomery College												
Data Processing Program in Dept. of Business Administration									X			
Hudson Valley Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Kingsborough Community College												
Computer Science Program in Several Depts.	X				X				X			
Data Processing Program in Several Depts.	X				X				X			
Mercy College												
Computer Science Program in Dept. of Computer Science						X				X		
Monroe Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Nassau Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			
New York City Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
New York Institute of Technology, Main Campus												
Computer Science Program in Dept. of Computer Technology		X				X				X		
New York University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Mathematics			X	X			X	X			X	X
Computer Science Program in Dept. of Electrical Engineering			X	X			X	X			X	X
Computer Science Program in Dept. of Industrial Engineering			X	X			X	X			X	X
Niagara County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Onondaga Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Orange County Community College												
Computer Programming Program in Dept. of Engineering	X											
Data Processing Program in Dept. of Business Administration	X				X				X			
Pace College												
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Information Systems Program in Dept. of Other	X				X				X			
Pace College, Westchester												
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Polytechnic Institute of Brooklyn												
Computer Science Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
Queensborough Community College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Data Processing Program in Dept. of Business Administration					X				X			
Rensselaer Polytechnic Institute, Main Campus												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X

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	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
St. Francis College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Statland Island Community College												
Computer Science Program in Dept. of Other	X				X				X			
Suffolk Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Alfred												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Canton												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Cobleskill												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Delhi												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Farmingdale												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College, Morrisville												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY College at Oswego												
Computer Science Program in Dept. of Computer Science						X				X		
SUNY State University at Albany												
Computer Science Program in Dept. of Computer Science			X				X				X	
SUNY State University Buffalo, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
SUNY State University Stony Brook, Main Campus												
Computer Science Program in Dept. of Computer Science			X	X		X	X	X		X	X	X

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
SUNY Downstate Medical Center												
Computer Science Program in Dept. of Computer Science		X				X	X			X	X	
Syracuse University												
Computer Engineering in Dept. of Electrical Engineering										X		
System Information Science Program in Dept. of System Information Science			X	X			X	X			X	X
Union College												
Computer Science Program in Dept. of Computer Science		X				X				X	X	
Voorhees Technical Institute												
Computer Science Program in Dept. of Computer Science	X				X				X			
Westchester Community College												
Data Processing Program in Dept. of Data Processing					X				X			
NORTH CAROLINA												
Caldwell Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Durham Technical Institute												
Data Processing Program in Dept. of Business Administration									X			
East Carolina University, Main Campus												
Information Science Program in Dept. of Mathematics						X						
Fayetteville Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
Gardner Webb College												
Data Processing Program in Dept. of Data Processing						X						
Guilford College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Guilford Technical Institute												
Data Processing Program in Dept. of Business	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Lenoir Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
N.C. State University, Raleigh, Main Campus												
Computer Science Program in Dept. of Computer		X				X				X	X	
Richmond Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
Rockingham Community College												
Data Processing Program in Dept. of Computer Science	X				X				X			
Rowan Technical Institute												
Data Processing Program in Dept. of Business					X				X			
Technical Institute of Alamance												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of North Carolina at Ashville												
Computer Science Program in Dept. of Mathematics		X				X				X		
University of North Carolina Chapel Hill												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
Wayne Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Wilkes Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Wingate College												
Computer Programming Program in Dept. of Computer Science	X				X				X			
NORTH DAKOTA												
Bismark Junior College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
North Dakota State School of Science												
Computer Programming Program in Dept. of Computer Programming	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
North Dakota State University, Main Campus												
Computer Science Program in Dept. of Mathematics		X				X				X		
Valley City State College												
Computer Programming Program in Dept. of Mathematical Sciences		X				X				X		
OHIO												
Bowling Green State University												
Computer Science Program in Dept. of Computer Science		X				X				X	X	
Information Systems Program in Dept. of Other		X				X				X		
Case Western Reserve University												
Computer Science Program in Dept. of Computer and Information Science			X	X		X	X	X		X	X	X
Cleveland State University												
Computer Science Program in Dept. of Computer and Information Science						X				X		
College of Wooster												
Computer Science Program in Dept. of Mathematics		X				X				X		
Cuyahoga Community College, Metro Campus												
Data Processing Program in Dept. of Business Administration	X				X				X			
Cuyahoga Community College, Western Campus												
Data Processing Program in Dept. of Business Administration	X				X				X			
Kent State University, Main Campus												
Information Systems Program in Dept. of Business Administration										X		
Lakeland Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Muskingum Area Technical Institute												
Computer Science Program in Dept. of Business					X				X			
Ohio State University												
Computer Science Program in Dept. of Computer and Information Science		X	X	X		X	X	X		X	X	X

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Ohio State University, Main Campus												
Computer Science Program in Dept. of Computer Science		X				X				X		
Data Processing Program in Dept. of Other		X	X			X	X			X	X	
Sinclair Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
University of Cincinnati, Main Campus												
Data Processing Program in Dept. of Other	X				X				X			
Data Processing Program in Dept. of Other	X				X				X			
Data Processing Program in Dept. of Other	X				X				X			
University of Dayton												
Computer Science Program in Dept. of Computer Science		X				X				X		
Wright State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Other Program in Dept. of Business		X				X				X		
Systems Engineering Program in Dept. of Systems Engineering		X	X			X	X			X	X	
OKLAHOMA												
Central State University												
Computer Science Program in Dept. of Mathematics		X				X				X		
Eastern Oklahoma State College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Langston University												
Data Processing Program in Dept. of Data Processing	X				X				X			
Northeastern Oklahoma Agricultural-Mechanical College												
Computer Programming Program in Dept. of Computer Science	X				X				X			
Northern Oklahoma College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Oklahoma State University, Main Campus												
Computer Science Program in Dept. of Computer and Information Science			X				X				X	

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Oklahoma State University, Oklahoma City												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Southwestern State College												
Computer Science Program in Dept. of Computer Science	X				X				X			
University of Oklahoma, Main Campus												
Computer Programming Program in Dept. of Information and Computer Science				X				X				X
University of Tulsa												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
OREGON												
Blue Mountain Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Central Oregon Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Chemeketa Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Clackamas Community College												
Computer Programming Program in Dept. of Computer Technology									X			
Lane Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Oregon Technical Institute												
Computer Technology Program in Dept. of Other	X	X			X	X			X	X		
Portland State University												
Systems Sciences Program in Dept. of Systems Sciences								X				X
Southwestern Oregon Community College												
Data Processing Program in Dept. of Business	X				X				X			
University of Oregon, Main Campus												
Computer Science Program in Dept. of Computer Science						X	X			X	X	

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
PENNSYLVANIA												
Bloomsburg State College												
Information Processing Program in Dept. of Information Processing										X		
Bucks County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Butler County Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Community College of Delaware County												
Data Processing Program in Dept. of Business Administration	X				X				X			
Community College of Philadelphia												
Computer Science Program in Dept. of Computer Science	X				X				X			
Drexel University												
Data Processing Program in Dept. of Business Administration		X	X			X	X			X	X	
Duquesne University												
Information Science Program in Dept. of Business Administration			X				X				X	
East Stroudsberg State College												
Computer Science Program in Dept. of Mathematics										X		
Indiana University of Pennsylvania												
Computer Programming Program in Dept. of Mathematics		X				X				X		
Systems Analysis Program in Dept. of Business Administration		X				X				X		
King's College												
Data Processing Program in Dept. of Data Processing		X				X				X		
Lehigh University												
Information Science Program in Dept. of Information Science			X	X			X	X			X	X
Lock Haven State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Montgomery County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Northampton County Area Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Pennsylvania State University, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Pennsylvania State University, Scranton Campus												
Computer Science Program in Dept. of Computer Science					X				X			
Point Park College												
Information Science Program in Dept. of Information Science		X				X				X		
Spring Garden College												
Computer Science Program in Dept. of Computer Programming	X				X				X			
Computer Technology Program in Dept. of Computer Technology					X				X			
Susquehana University												
Other Program in Dept. of Mathematical Sciences		X										
University of Pittsburgh												
Systems Engineering Program in Dept. of Electrical Engineering			X	X			X	X		X	X	X
Computer Science Program in Dept. of Computer			X	X			X	X			X	X
University of Scranton												
Computer Science Program in Dept. of Computer Science									X	X		
Williamsport Area Community College												
Data Processing Program in Several Departments	X				X				X			
PUERTO RICO												
University of Puerto Rico, Rio Piedras												
Computer Programming Program in Dept. of Business Administration		X				X				X		
RHODE ISLAND												
Brown University												
Computer Science Program in Dept. of Other		X	X	X		X	X	X		X	X	X
Bryant College of Business Administration												
Information Systems Program in Dept. of Other						X				X		

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Johnson and Wales Junior College of Business												
Data Processing Program in Dept. of Data Processing	X				X				X	X		
Rhode Island Junior College												
Computer Programming Program in Dept. of Data Processing					X				X			
University of Rhode Island												
Computer Science Program in Dept. of Systems and Computer Science			X				X				X	
SOUTH CAROLINA												
Berk-Chastn-Dorchester Technical Education Center												
Data Processing Program in Dept. of Data Processing	X				X				X			
Clemson University												
Computer Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
Systems Engineering Program in Dept. of Engineering			X	X			X	X			X	X
Florence Darlington Technical Education Center												
Data Processing Program in Dept. of Data Processing	X				X				X			
Greenville Technical Education Center												
Data Processing Program in Dept. of Data Processing	X				X				X			
Midlands Technical Education Center												
Data Processing Program in Dept. of Data Processing	X				X				X			
Palmer College Columbia												
Data Processing Program in Dept. of Business Administration	X				X				X			
Spartanberg County Technical Education Center												
Computer Programming Program in Dept. of Data Processing	X				X				X			
University of South Carolina, Main Campus												
Computer Science Program in Dept. of Computer Science		X				X				X		
York County Technical Education Center												
Data Processing Program in Dept. of Data Processing	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
SOUTH DAKOTA												
National College of Business												
Computer Programming Program in Dept. of Data Processing	X	X			X	X			X	X		
University of South Dakota												
Computer Science Program in Dept. of Mathematics		X				X				X		
TENNESSEE												
Chattanooga State Technical Institute												
Information Systems Program in Dept. of Computer Science	X				X				X			
Computer Science Program in Dept. of Computer Science	X				X				X			
Data Processing Program in Dept. of Computer Science	X				X				X			
Columbia State Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Lambuth College												
Data Processing Program in Dept. of Business Administration		X				X				X		
Middle Tennessee State University												
Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
Nashville State Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
State Technical Institute												
Data Processing Program in Dept. of Computer Technology	X				X				X			
University of Tennessee At Chattanooga												
Computer Science Program in Dept. of Computer Science	X				X				X			
University of Tennessee, Knoxville												
Computer Science Program in Several Departments							X				X	
Vanderbilt University												
Computer Science Program in Dept. of Systems and Information Sciences		X				X	X	X		X	X	X
TEXAS												
Alvin Junior College												
Computer Science Program in Dept. of Computer Science	X				X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Amarillo College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Bee County College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Blinn College												
Computer Science Program in Dept. of Computer Science									X			
Brazosport Junior College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Cisco Junior College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Cooke County Junior College												
Computer Programming Program in Dept. of Business Administration	X				X				X			
Dallas County Junior College District												
Data Processing Program in Dept. of Business Administration	X				X				X			
Del Mar College												
Data Processing Program In Dept. of Data Processing	X				X				X			
East Texas State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Henderson County Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Hill Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Laredo Junior College												
Data Processing Program In Dept. of Data Processing	X				X				X			
Lee College												
Data Processing Program In Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
McLennan Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Navarro Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Odessa College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Rice University												
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
San Antonio College												
Data Processing Program In Dept. of Data Processing	X				X				X			
San Jacinto College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Southern Methodist University												
Computer Science Program in Dept. of Computer Science			X	X			X	X		X	X	X
Information and Computer Science in Dept. of Information and Computer Science		X	X	X		X	X	X		X	X	X
South Plains College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Tarrant County Junior College, Northeast Campus												
Data Processing Program in Dept. of Business Administration	X				X				X			
Tarrant County Junior College, South Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			
Texarkana College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Texas A & I University												
Data Processing Program in Dept. of Data Processing		X				X				X		

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Texas A&M University												
Computer Science Program in Dept. of Industrial Engineering			X				X	X			X	X
Texas Christian University												
Computer Science Program in Dept. of Mathematical Sciences						X				X		
Texas State Technical Institute												
Computer Technology Program in Dept. of Computer Science	X				X				X			
University of Houston												
Computer Science Program in Dept. of Computer Science			X				X				X	
Computer Technology Program in Dept. of Electrical Engineering Technology		X				X				X		
Systems Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Systems Engineering Program in Dept. of Industrial Engineering		X	X	X		X	X	X		X	X	X
University of St. Thomas												
Computer Programming Program in Dept. of Mathematics		X				X				X		
University of Texas at Austin												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
West Texas State University												
Computer Science Program in Dept. of Information Systems						X	X			X	X	
Data Processing Program in Dept. of Business Administration		X	X									
UTAH												
Brigham Young University												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
Utah State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Weber State College												
Data Processing Program in Dept. of Data Processing	X	X			X	X			X	X		

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
VERMONT												
Champlain College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
VIRGINIA												
Central Virginia Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
College of William and Mary, Main Campus												
Computer Science Program in Several Departments							X				X	
Danville Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Hampden-Sydney College												
Computer Science Program in Dept. of Mathematics										X		
Northern Virginia Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Richard Bland College of William and Mary												
Data Processing Program in Dept. of Business	X				X				X			
Tidewater Community College												
Computer Programming Program in Dept. of Business Administration					X				X			
Virginia Commonwealth University												
Information Systems Program in Dept. of Information Systems	X				X				X			
Virginia Polytechnic Institute and State University												
Computer Science Program in Dept. of Computer Science		X				X				X	X	
Virginia Western Community College												
Computer Programming Program in Dept. of Data Processing					X				X			
WASHINGTON												
Big Bend Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Data Processing Program in Dept. of Computer Science	X				X				X			
Everett Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1971 SURVEY

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Fort Steilacoom Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Grays Harbor College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Highline Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Lower Columbia College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Olympic College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Seattle Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Spokane Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Washington State University												
Computer Science Program in Dept. of Computer Science			X	X		X	X	X		X	X	X
Western Washington State College												
Computer Science Program in Dept. of Mathematics						X				X		
Yakima Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
WEST VIRGINIA												
Bethany College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Potomac State College of West Virginia University												
Computer Technology Program in Dept. of Computer Science	X				X				X			
Shepherd College												
Data Processing Program in Dept. of Business Administration					X	X			X	X		

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
West Liberty State College, Main Campus												
Data Processing Program in Dept. of Business Administration	X	X			X	X						
West Virginia Institute of Technology												
Computer Science Program in Dept. of Computer Science						X				X		
West Virginia University, Main Campus												
Computer Science Program in Dept. of Statistics and Computer Science		X				X				X		
West Virginia University, Parkersburg Center												
Computer Science Program in Dept. of Computer Science									X			
WISCONSIN												
District One Technical Institute												
Data Processing Program in Dept. of Business Administration	X				X				X			
Lawrence Institute of Technology												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Milwaukee School of Engineering												
Computer Technology Program in Dept. of Electrical Engineering	X				X				X			
University of Wisconsin, Milwaukee												
Computer Technology Program in Dept. of Electrical Engineering		X				X	X			X	X	
Information Systems Program in Dept. of Business Administration		X				X				X		
University of Wisconsin, Madison												
Data Processing Program in Dept. of Physical Sciences		X		X		X		X		X		
Wisconsin State University at LaCrosse												
Computer Science Program in Dept. of Computer Science										X		
Wisconsin State University at Superior												
Data Processing Program in Dept. of Business Administration		X				X				X		
Waukesha County Technical Institute												
Data Processing Program in Dept. of Data Processing					X				X			

	69-70				70-71				71-72			
	A	B	M	D	A	B	M	D	A	B	M	D
Western Wisconsin Technical Institute												
Computer Programming Program in Dept. of Data Processing	X				X				X			
WYOMING												
Casper College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Northwest Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
University of Wyoming												
Computer Science Program in Dept. of Computer Science										X		

APPENDIX B

Institutions Reporting Computer-Related Degree Programs as of June 30, 1978

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
ALABAMA												
Alabama State University												
Information Systems Program in Dept. of Information Systems	X	X			X	X			X	X		
Auburn University at Montgomery												
Other Program in Dept. of Information Systems		X				X				X		
Chattahoochee Valley Community College												
Computer Science Program in Dept. of Data Processing	X				X				X			
Jefferson State Junior College												
Data Processing Program in Dept. of Computer Science	X				X				X			
Livingston University												
Data Processing Program in Dept. of Computer Science		X				X				X		
Lurleen B. Wallace State Junior College												
Computer Science Program in Dept. of Data Processing	X				X				X			
Northeast Alabama State Junior College												
Data Processing Program a Dept. of Data Processing	X				X				X			
Troy State University, Dothan--Ft. Rucker												
Computer Science Programs Dept. of Business						X				X		
University of Alabama												
Computer Science Program in Several Departments			X				X				X	
University of Alabama in Brimingham												
Computer Science Programs Dept. of Computer and Information Sciences		X	X	X		X	X	X		X	X	X
University of Alabama in Huntsville												
Computer Science Program in Dept. of Computer Science			X				X				X	
ARIZONA												
Arizona State University												
Computer Science Program in Dept. of Industrial		X	X	X		X	X	X		X	X	X
Computer Science and Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
Information Systems Program in Dept. of other		X				X				X		
Central Arizona College												
Other Program in Dept. of Business Administration	X				X				X			

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Glendale Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Maricopa Technical Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Mesa Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Northern Arizona University												
Data Processing Program in Dept. of Business Administration		X				X				X		
Computer Science Program in Dept. of Computer Science		X				X				X		
Phoenix College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Pima Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Scottsdale Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
University of Arizona												
Computer Engineering Program in Dept. of Electrical Engineering							X			X	X	X
Yavapai College												
Data Processing Program in Dept. of Data Processing	X				X				X			
ARKANSAS												
Arkansas State University, Main Campus												
Data Processing Program in Dept. of Business		X				X				X		
Arkansas Technical University												
Information Science Program in Dept. of Computer Science		X				X				X		
Harding College, Main Campus												
Computer Programming Program in Dept. of Mathematics		X				X				X		

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
University of Arkansas, Main Campus												
Data Processing Program in Dept. of Computer Science		X				X				X		
Computer Science Program in Dept. of Industrial Engineering		X				X				X		
Computer Science Program in Dept. of Mathematical Sciences		X	X			X	X			X	X	
Computer Science Program in Dept. of Computer Science			X				X				X	
University of Arkansas at Little Rock												
Computer Science Program in Dept. of Computer Science		X				X				X		
CALIFORNIA												
American River College												
Data Processing Program in Dept. of Data Processing	X				X				X			
California Institute of Technology												
Other Program in Dept. of Computer Science			X	X			X	X			X	X
California State Poly. University--Pomona												
Data Processing Program in Dept. of Computer Science		X				X				X		
California State Poly. University--San Luid Obiapo												
Computer Science Program in Dept. of Systems and Computer Science		X	X			X	X			X	X	
California State University--Chico												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
California State University--Fullerton												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
California State University--Long Beach												
Computer Science and Engineering Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
California State University--Pomona												
Computer Science Program in Dept. of Computer Science		X				X				X		
Chabot College												
Data Processing Program in Dept. of Data Processing	X				X				X			

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Chaffey College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Citrus College												
Data Processing Program in Dept. of Information Systems	X				X				X			
College of Marin												
Computer Science Program in Dept. of Mathematics	X				X				X			
College of Notre Dame												
Information Science Program in Dept. of Business Administration						X				X		
College of the Siskiyous												
Data Processing Program in Dept. of Data Processing	X				X				X			
Contra Costa College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Diablo Valley College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Golden Gate University												
Information Science Program in Dept. of Business Administration						X				X		
Long Beach City College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Other Program in Dept. of Mathematics	X				X				X			
Los Angeles Valley College												
Information and Computer Science Program in Dept. of Computer and Information Science	X				X				X			
Merced College												
Computer Science Program in Dept. of Computer and Information Science	X				X				X			
Monterey Pen College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mount San Antonio College												
Data Processing Program in Dept. of Computer	X				X				X			
Computer Technology Program in Dept. of Computer Science	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Orange Coast College												
Information Systems Program in Dept. of Information Systems	X				X				X			
Palomar College												
Computer Science Program in Dept. of Business Administration	X				X				X			
Point Loma College												
Computer Science Program in Dept. of Mathematics	X				X				X			
Santa Ana College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Computer Science Program in Dept. of Computer Science	X				X				X			
Santa Barbara City College												
Computer Science Program in Dept. of Computer Science	X				X				X			
San Joaquin Delta College												
Data Processing Program in Dept. of Computer Science	X				X				X			
Shasta College												
Computer Programming Program in Dept. of Business Administration	X				X				X			
Sierra College												
Computer Programming Program in Dept. of Computer and Information Science	X				X				X			
Stanford University												
Information Systems Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
University of California--Davis												
Computer Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Computer Science Program in Dept. of Other			X	X			X	X			X	X
University of California--Irvine												
Information and Computer Science Program in Dept. of Information and Computer Science		X	X	X		X	X	X		X	X	X
University of California--Los Angeles												
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X

INSTITUTIONS REPORTING COMPUTER RELATED DEGREE PROGRAMS IN JUNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
University of California--San Diego												
Computer Science Program in Dept. of Other		X	X	X		X	X	X		X	X	X
University of California--San Francisco												
Information Science Program in Dept. of Information Science			X	X			X	X			X	X
University of California--Santa Barbara												
Computer Science and Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
University of California--Santa Cruz												
Information Science Program in Dept. of Information Science		X	X	X		X	X	X		X	X	X
University of Southern California												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Other Program in Dept. of Electrical Engineering				X				X				X
Westmont College												
Other Program in Dept. of Mathematics		X				X				X		
West Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
COLORADO												
Community College of Denver, Central Office												
Data Processing Program in Dept. of Business	X				X				X			
El Paso Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mesa College												
Computer Science Program in Several Departments	X	X			X	X			X	X		
Data Processing Program in Dept. of Data Processing	X				X				X			
Otero Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Trinidad State Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Colorado at Boulder												
Computer Science and Engineering Program in Dept. of Electrical Engineering		X				X				X		

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DEGREE PROGRAMS IN JUNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Information Systems Program in Dept. of Business Administration		X				X				X		
Computer Science Program in Dept. of Computer Science			X	X			X	X			X	X
University of Colorado Medical Center												
Other Program in Dept. of Other			X	X			X	X			X	X
University of Denver												
Computer Science Program in Dept. of Mathematics		X				X	X			X	X	
CONNECTICUT												
Annhurst College												
Other Program in Dept. of Mathematics										X		
Central Connecticut State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Greater Hartford Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Manchester Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Quinnipac College												
Information System Program in Dept. of Information Systems	X	X			X	X			X	X	X	
Thames Valley State Technical College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Trinity College												
Other Program in Dept. of Engineering						X				X		
United States Coast Gruard Academy												
Mathematical Sciences Program in Dept. of Computer Science		X				X				X		
University of Hartford												
Computer Science and Engineering Program in Dept. of Electrical Engineering		X				X				X		
Computer Science Program in Dept. of Mathematics						X				X		
University of New Haven												
Computer Science Technology Program in Dept. of Industrial Engineering		X	X			X	X			X	X	

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
DELAWARE												
Delaware Technical and Community College												
Data Processing Program in Dept. of Data	X				X				X			
DISTRICT OF COLUMBIA												
The Catholic University of America												
Other Program in Dept. of Other										X		
Information Science Program in Dept. of Other			X				X				X	
George Washington University												
Other Program in Dept. of Systems and Computer Science		X				X				X		
Howard University												
Computer Science Program in Dept. of Computer Science			X				X				X	
Washington Technical Institute												
Other Program in Dept. of Computer and Information Science	X				X					X		
FLORIDA												
Brevard Community College												
Computer Programming Program in Dept. of Business	X				X				X			
Broward Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Chipola Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Deytona Beach Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Edison Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Florida Agricultural and Mechanical College												
Data Processing Program in Dept. of Computer Science		X				X				X		
Florida Keys Community College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Florida State University												
Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
Florida Technological University												
Computer Engineering Program in Dept. of Electrical Engineering		X	X			X	X			X	X	
Gulf Coast Community College												
Computer Science Program in Dept. of Data Processing	X				X				X			
Manatee Junior College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Miami-Dade Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Okaloosa-Walton Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Polk Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
St. John's River Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Tallahassee Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
University of Miami												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
University of North Florida												
Computer Science Program in Dept. of Mathematical Sciences		X				X	X			X	X	
University of South Florida												
Computer Science Program in Dept. of Electrical Engineering		X	X			X	X			X		X
University of West Florida												
Systems Science Program in Dept. of Systems Science		X	X			X	X			X		X

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
GEORGIA												
Abraham Baldwin Agricultural College												
Computer Science Program in Dept. of Business Administration	X				X				X			
Atlanta Junior College												
Computer Science Program in Several Departments	X				X				X			
Brunswick Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Computer Science Program in Dept. of Mathematical Sciences	X				X				X			
Columbus College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Gainesville Junior College												
Business Administration Program in Dept. of Business Administration	X				X				X			
Georgia Institute of Technology												
Information and Computer Science Program in Dept. of Information and Computer Science		X	X	X		X	X	X		X	X	X
Georgia Institute of Technology--Southern Tech												
Computer Science Technology Program in Dept. of Electrical Engineering Technology	X				X				X			
Middle Georgia College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Talladega College												
Other Program in Dept. of Mathematics		X				X				X		
University of Georgia												
Computer Science Program in Dept. of Systems and Computer Science		X	X	X		X	X	X		X	X	X
Other Program in Dept. of Business Administra-		X	X	X		X	X	X		X	X	X
West Georgia College												
Computer Science Program in Dept. of Mathematics	X				X				X			
HAWAII												
University of Hawaii, Kapiolani Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
IDAHO												
Boide State University												
Information Science Program in Dept. of Business Administration		X				X				X		
Idaho State University												
Information and Computer Science Program in Dept. of Business Administration		X				X				X		
ILLINOIS												
Bradley University												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Carl Sandburg College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Chicago State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
College of Dupage												
Data Processing Program in Dept. of Data Processing	X				X				X			
College of Lake County												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Eastern Illinois University												
Other Program in Dept. of Mathematics		X				X				X		
Other Program in Dept. of Other		X				X				X		
Highland Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Illinois Institute of Technology												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Illinois State University												
Computer Science Program in Dept. of Mathematics		X				X				X		
John A. Logan College												
Other Program in Dept. of Business Administration	X				X				X			
Joliet Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Kan KaKee Community College												
Computer Programming Program in Dept. of Business	X				X				X			
Lewis and Clark Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Lewis University												
Computer Science Program in Dept. of Other		X				X				X		
Loyola University of Chicago												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
McHenry County College												
Data Processing Program in Dept. of Business	X				X				X			
Northeastern Illinois University												
Information and Computer Science Program in Dept. of Information and Computer Science		X				X				X		
Northwestern University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Olivet Nazarene College												
Computer Science Program in Dept. of Computer Science		X				X				X		
Prairie State College												
Computer Programming Program in Dept. of Information Systems	X				X				X			
Quincy College												
Information Science Program in Dept. of Information Science	X	X			X	X			X	X		
Rock Valley College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Sauk Valley College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Southern Illinois University, Carbondale												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Data Processing Program in Dept. of Data Processing	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Thornton Community College												
Data Processing Program in Dept. of Business	X				X				X			
University of Illinois, Chicago Circle												
Computer Science Program in Dept. of Mathematics		X				X				X		
Computer Science and Engineering Program in Dept. of Computer Science and Engineering		X	X	X		X	X	X		X	X	X
University of Illinois, Urbana Campus												
Computer Engineering Program in Dept. of Electrical Engineering		X				X				X		
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Waubonsee Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Western Illinois University												
Statistics and Computer Science Program in Dept. of Statistics and Computer Science		X				X				X	X	
INDIANA												
Anderson College												
Computer Science Program in Dept. of Computer Science		X				X				X		
Butler University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Calumet College												
Computer Science Program in Dept. of Computer Science	X				X				X			
DePauw University												
Other Program in Dept. of Other		X				X				X		
Indiana Central University												
Computer Technology Program in Dept. of Business Administration	X				X				X			
Indiana University at Bloomington												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	X
Other Program in Dept. of Other			X				X				X	
Indiana University at South Bend												
Other Program in Dept. of Business Administration		X				X				X		

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Indiana-Purdue University at Fort Wayne												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Computer Technologyprogram in Dept. of Computer Technology	X	X			X	X			X	X		
Indiana--Purdue University at Indianapolis												
Computer Science Program in Dept. of Mathematical Science		X	X			X	X			X	X	
Indiana Vocational Technical College, Central												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Indiana Vocational Technical College--Kokomo												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Indiana Vocational Technical College-South Bend												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Manchester College												
Other Program in Dept. of Mathematics	X				X				X			
Purdue University, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Purdue University, Calumet Campus												
Computer Programming Program in Dept. of Information Systems	X	X			X	X			X	X		
Computer Science Program in Dept. of Mathematics		X				X				X		
Purdue University North Central												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Rose-Hulman Institute of Technology												
Computer Science Program in Dept. of Computer Science		X				X				X		
St. Joseph's College												
Information and Computer Science Program in Dept. of Information and Computer Science	X	X			X	X			X	X		
Taylor University												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
University of Evansville												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		

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IOWA	76-77 A	76-77 B	76-77 M	76-77 D	77-78 A	77-78 B	77-78 M	77-78 D	78-79 A	78-79 B	78-79 M	78-79 D
Central University of Iowa												
Computer Science Program in Dept. of Mathematics		X				X				X		
Drake University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Information System Program in Dept. of Information Systems		X				X				X		
Graceland College												
Computer Science Program in Dept. of Other		X				X				X		
Iowa Central Community College												
Data Processing Program in Dept. of Business Administration					X				X			
Iowa State University												
Computer Engineering Porgram in Dept. of Electrical Engineering						X				X		
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Iowa Western Community College, Central Office												
Other Program in Dept. of Data Processing	X				X				X			
Iowa Western Community College, Council Bluff												
Data Processing Program in Dept. of Data Processing	X				X				X			
Kirkwood Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			
Luther College												
Computer Science Program in Dept. of Computer Science		X				X				X		
St. Ambrose College												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
University of Iowa												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
University of Northern Iowa												
Other Program in Dept. of Mathematics		X				X				X		
Western Iowa Technical Community College												
Computer Programming Program in Dept. of Data Processing	X				X				X			

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KANSAS	76-77 A	76-77 B	76-77 M	76-77 D	77-78 A	77-78 B	77-78 M	77-78 D	78-79 A	78-79 B	78-79 M	78-79 D
Barton County Community Junior College												
Data Processing Program in Several Departments	X				X				X			
Cowley County Community Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Emporia State University												
Data Processing Program in Dept. of Business	X	X	X		X	X	X		X	X	X	
Fort Hayes State University												
Data Processing Program in Dept. of Business		X				X				X		
Johnson County Community Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Kansas City Kansas Community Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Kansas State University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Kansas Technical Institute												
Computer Science Program in Dept. of Computer Technology	X				X				X			
Pittsburg State University												
Computer Science Program in Dept. of Information and Computer Science		X				X				X		
Information Systems Program in Dept. of Information and Computer Science	X	X			X	X			X	X		
Seward County Community Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Kansas												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Washburn University of Topeka												
Computer Science Program in Dept. of Mathematics	X	X			X	X			X	X		

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
KENTUCKY												
Eastern Kentucky University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Kentucky State University												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
Morehead State University												
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Northern Kentucky University												
Data Processing Program in Dept. of Business Administration	X				X				X			
Transylvania University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Union College												
Computer Science Program in Dept. of Computer Science	X				X				X			
University of Louisville												
Systems Computer Engineering Program in Dept. of Engineering		X	X			X	X			X	X	
Data Processing Program in Dept. of Engineering	X				X				X			
Western Kentucky University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Data Processing Program in Dept. of Other	X				X				X			
LOUISIANA												
Louisiana State University												
Computer Science Program in Dept. of Computer Science		X					X				X	
Systems Science Program in Dept. of Computer Science			X				X				X	
Louisiana Tech University												
Systems and Information Science in Dept. of Industrial Engineering		X				X				X		
Loyola University in New Orleans												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		

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	A	B	M	D	A	B	M	D	A	B	M	D
Nicholls State University												
Computer Science Program in Dept. of Computer and Information Science		X				X				X		
Computer Programming Program in Dept. of Computer and Information Science	X				X				X			
Northeast Louisiana University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Data Processing Program in Dept. of Business Administration		X				X				X		
Northwestern State University of Louisiana												
Computer Technology Program in Dept. of Business Administration	X				X				X			
Southern University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Tulane University												
Computer Science Program in Dept. of Mathematics		X				X				X		
MAINE												
Beal Business College												
Data Processing Program in Dept. of Business	X				X				X			
University of Maine at Orono												
Computer Science Program in Several Departments		X				X				X		
Systems Engineering Porgram in Dept. of Engineering			X				X					X
MARYLAND												
Allegany Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Anne Arundel Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Columbia Union College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Essex Community College												
Data Processing Program in Dept. of Other	X				X				X			
Hagerstown Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Harford Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Howard Community College												
Data Processing Program in Dept. of Business	X				X				X			
Johns Hopkins University												
Other Program in Dept. of Mathematical Sciences		X	X	X		X	X	X		X	X	X
Loyola College												
Computer Science Program in Dept. of Other		X				X				X		
Montgomery College, Takoma Park												
Computer Science Program in Dept. of Mathematics	X				X				X			
Towson State University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
University of Baltimore												
Data Processing Program in Dept. of Business Administration		X				X				X		
University of Maryland, College Park Campus												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Computer Science and Engineering Program in Dept of Electrical Engineering		X	X	X		X	X	X		X	X	X
Information Systems Program in Dept. of Information Systems		X				X				X		
Other Program in Dept. of Other		X				X				X		
Washington College												
Other Program in Dept. of Mathematical Sciences		X				X				X		
MASSACHUSETTS												
Atlantic Union College												
Computer Programming Program in Dept. of Mathematics	X				X				X			
Bentley College												
Information Systems Porgram in Dept. of Computer and Information Science		X				X				X		
Boston University												
Computer Science Program in Dept. of Mathematics		X	X	X		X	X	X		X	X	X
Computer Engineering Program in Dept. of Engineering		X	X			X	X			X	X	

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	A	B	M	D	A	B	M	D	A	B	M	D
Bristol Community College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Cape Cod Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Holyoke Community College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Massachusetts Institute of Technology												
Computer Science Program in Dept. of Other		X	X	X		X	X	X		X	X	X
Information Systems Program in Dept. of Other			X	X			X	X			X	X
Massasoit Community College												
Data Processing Program in Dept. of Computer Science	X				X				X			
Mt. Wachusett Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Newbury Junior College												
Data Processing Program in Dept. of Business Administration	X				X				X			
North Shore Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
University of Lowell												
Computer Engineering Program in Dept. of Electrical Engineering			X				X				X	
University of Massachusetts, Amherst Campus												
Computer Science Porgram in Dept. of Computered Information Science		X	X	X		X	X	X		X	X	X
Computer Engineering Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Wentworth Institute												
Computer Science Technology Program in Dept of Computer Science	X				X				X			
Worcester Polytechnic Institute												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X		X

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
MICHIGAN												
Albion College												
Other Program in Dept. of Mathematics		X				X				X		
Charles S. Mott Community College												
Data Processing Program in Dept. of Systems Science	X				X				X			
Davenport College of Business												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Detroit College of Business												
Data Processing Porgram in Dept. of Computer Science	X	X			X	X			X	X		
Gogebic Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Lansing Community College												
Data Processing Program in Dept. of Other	X				X				X			
Macomb County Community College, Central Office												
Data Processing Program in Dept. of Data Processing	X				X				X			
Madonna College												
Computer Science Program in Dept. of Business Administration	X	X			X	X			X	X		
Michigan State University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Monroe County Community College												
Data Processing Program in Dept. of Business	X				X				X			
Muskegon Business College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Northern Michigan University												
Computer Science Program in Dept. of Mathematics		X				X				X		
Data Processing Programic Several Departments	X				X				X			
Northwestern Michigan College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	L
Oakland Community College												
Data Processing Program in Dept. of Computer Science	X				X				X			
Oakland University												
Computer Science Program in Dept. of Engineering		X				X				X		
St. Clair County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Schoolcraft College												
Data Processing Program in Dept. of Computer and Information Science	X				X				X			
Suomi College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Detroit												
Computer Science Program in Dept. of Mathematics			X				X				X	
University of Michigan--Flint												
Computer Science Program in Dept. of Computer Science						X				X		
University of Michigan												
Information Systems Program in Dept. of Industrial Engineering		X	X	X		X	X	X		X	X	X
Data Processing Program in Dept. of Business Administration			X	X			X	X			X	X
Computer Science Program in Dept. of Mathematics			X	X			X	X			X	X
Washtenaw Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Wayne County Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Western Michigan University												
Computer Science Program in Dept. of Mathematics			X			X	X			X	X	
Data Processing Program in Dept. of Business Administration		X				X				X		
Other Program in Dept. of Electrical Engineering		X				X				X		

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	A	B	M	D	A	B	M	D	A	B	M	D
West Shore Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
MINNESOTA												
College of St. Thomas												
Computer Science Program in Dept. of Computer and Information Science		X				X				X		
Concordia College at Moorhead												
Computer Science Program in Dept. of Computer Science						X				X		
Mankato State University												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Minnesota Technical Institute, Crookston												
Data Processing Program in Dept. of Business	X				X				X			
Moorhead State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Northland Community College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
St. Cloud State University												
Computer and Information Science Program in Dept. of Business		X				X				X		
Computer Science Program in Dept. of Computer Science		X				X				X		
St. Mary's College												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Minnesota, Minneapolis, St. Paul												
Computer Science Program In Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Other Program in Dept. of Business Administration		X	X	X		X	X	X		X	X	X
Information Systems Program in Dept. of Information Systems			X	X			X	X			X	X
MISSISSIPPI												
Alcorn State University												
Computer Science Program in Dept. of Mathematics	X				X				X			
Copiah-Lincoln Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTI COMPUTER RELATED
DEGREE PROGRAMS IN JUNE 30, 1978 SURVEYS

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Ferris State College												
Data Processing Program in Dept. of Computer Science	X	X			X	X			X	X		
Itawamba Junior College												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Jackson State University												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Jones County Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mississippi Gulf Coast Junior College, Central Office												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mississippi State University												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Mississippi University for Women												
Data Processing Program in Dept. of Business Administration		X				X				X		
Pearl River Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Southwest Mississippi Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
University of Mississippi, Main Campus												
Computer Science Program in Dept. of Computer Science		X				X				X	X	
University of Southern Mississippi												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
William Carey College												
Data Processing Program in Dept. of Computer Science		X				X				X		

INSTITUTIONS REPORTI G COMPUTER RELATED
DEGREE PROGRAMS IN .UNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
MISSOURI												
Central Missouri State University												
Computer Science Porgram in Dept. of Mathematics		X				X				X		
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
Lincoln University												
Data Processing Porgram in Dept. of Other					X				X			
Longview Community College												
Other Program in Dept. of Business Administration	X				X				y			
Data Procepsing Program in Dept. of Business Administration	X				X				X			
Maryville College												
Information Science Program in Dept. of Mathematics		X				X				X		
Missouri Southern State College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Moberly Junior College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Northwest Missouri State University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Penn Valley Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
St. Louis Community College-Florissant Valley												
Data Processing Program in Dept. of Data Processing	X				X				X			
St. Louis Community College-Forest Park												
Data Processing Program in Dept. of Data Processing	X				X				X			
St. Louis Community College-Meramec												
Data Processing Program in Dept. of Data Processing	X				X				X			
St. Louis University												
Computer Science Program in Dept. of Mathematics		X				X				X		
Southeastern Missouri State University												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		

INSTITUTIONS REPORTI G COMPUTER RELATED
DEGREE PROGRAMS IN .UNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Southwest Missouri State University												
Data Processing Program in Dept. of Business		X				X				X		
University of Missouri, Columbia												
Computer Science Program in Dept. of Computer Science							X				X	
University of Missouri, Rolla												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Washington University												
Computer Science and Engineering Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Westminister College												
Computer Science Program in Dept. of Mathematics		X				X				X		
MONTANA												
Montana College Mineral Science-Technology												
Computer Science Program in Dept. of Mathematical Sciences	X				X				X			
Montana State University												
Computer Engineering Program in Dept. of Electrical Engineering		X				X				X		
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Montana												
Computer Science Program in Dept. of Computer Science		X				X				X		
NEBRASKA												
Kearney State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Metropolitan Technical Community College												
Computer Science Program in Dept. of Business Administration					X				X			
Midland Lutheran College												
Data Processing Program in Dept. of Business	X				X				X			
Peru State College												
Computer Programming Program in Dept. of Business Administration	X				X				X			
Southeast Community College, Milford Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			

INSTITUTIONS REPORTI G COMPUTER RELATED DEGREE PROGRAMS IN J NE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
NEW HAMPSHIRE												
New England Aeronautical Institute												
Computer Science Program in Dept. of Computer Science	X				X				X			
University of New Hampshire												
Computer Science Program in Several Departments		X				X				X	X	
NEW JERSEY												
Bergen Community College												
Computer Programming Program in Dept. of Business	X				X				X			
Burlington County College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Essex County College												
Information Processing Program in Dept. of Information Processing	X				X				X			
Farleigh-Dickensen, Teaneck Campus												
Computer Science Program in Several Departments		X	X			X	X			X	X	
Kean College of New Jersey												
Computer Science Program in Several Departments		X				X				X		
Monmouth College												
Computor Science Program in Dept. of Other		X				X				X		
Ocean County College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Passaic County Community College												
Data Processing Program in Dept. of Data Processing					X				X			
Richard Stockton State College												
Information Science Program in Dept. of Business Administration		X				X				X		
Rider College												
Other Program in Dept. of Other		X				X				X		
St. Peters College												
Computer Science Program in Dept. of Computer Science	X				X	X			X	X		
Seton Hall University												
Other Program in Dept. of Computer and Information Science										X		X

INSTITUTIONS REPORTI G COMPUTER RELATED DEGREE PROGRAMS IN : NE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Stevens Institute of Technology												
Other Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Trenton State College												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Union County Technical Institute												
Computer Science Program in Dept. of Computer Science	X				X				X			
NEW MEXICO												
Eastern New Mexico University, Central Office												
Computer Science Program in Dept. of Computer Science		X				X				X		
Computer and Information Science In Dept. of Computer and Information Science	X	X			X	X			X	X		
New Mexico Institute of Mining and Technology												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
NEW YORK												
Cayhuga County Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Corning Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
CUNY Boro of Manhattan Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
CUNY Bronx Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
CUNY Brooklyn College												
Computer Science Program in Dept. of Computer and Information Science		X				X				X	X	X
CUNY City College												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Dutchess Community College												
Data Processing Program in Dept. of Business	X				X				X			

INSTITUTIONS REPORTING COMPUTER RELATED
DEGREE PROGRAMS IN JUNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Elmira College												
Data Processing Porgram In Dept. of Business Administration	X	X			X	X			X	X		
Finger Lakes Community College												
Other Program in Dept. of Business Administration	X				X				X			
Genesee Community College												
Computer Programming Program in Dept. of Business Administration	X				X				X			
Hofstra University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Hudson Valley Community College												
Computer Science Program in Dept. of Data Processing	X				X				X			
Iona College												
Computer Science Program in Dept. of Computer and Information Science		X				X				X		
Jamestown Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Jefferson Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Long Island University, C.W. Post Center												
Computer Science Program in Dept. of Computer Science		X				X				X		
Other Program in Dept. of Other												
Mercy College												
Other Program in Several Depts.		X				X				X		
Monroe Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
New York Institute of Technology, New York City Campus												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
New York Institute of Technology, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	

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DEGREE PROGRAMS IN JUNE 30, 1978 SURVEY

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Niagara County Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Polytechnic Institute of New York												
Computer Science Program in Dept. of Electrical Engineering		X	X	X		X	X	X		X	X	X
Rensselaer Polytechnic Institute												
Computer Science Program in Dept. of Mathematical Sciences		X	X	X		X	X	X		X	X	X
Rochester Institute of Technology												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
St. Francis College												
Computer Science Program in Dept. of Data Processing	X				X				X			
St. John's University												
Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
Other Program in Dept. of Other		X	X			X	X			X	X	
Suffolk County Community College												
Other Program in Dept. of Electrical Engineering Technology	X				X				X			
Data Processing Program Dept. of Mathematics	X				X				X			
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College Canton												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY Agricultural and Technical College Cobleskill												
Data Processing Program in Dept. of Data Processing	X				X				X			
SUNY at Albany												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
SUNY College at Brockport												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
SUNY College at Buffalo												
Information Systems Program in Dept. of Information Systems		X				X				X		

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
SUNY College at Oswego Computer Science Program in Dept. of Computer Science		X				X				X		
Ulster County Community College Data Processing Program in Dept. of Computer Technology	X				X				X			
University of Rochester Computer Science Program in Dept. of Computer Science			X				X	X			X	X
Vassar College Computer Science Program in Dept. of Computer Science		X				X				X		
Westchester Community College Data Processing Program in Dept. of Other	X				X				X			
NORTH CAROLINA												
Asheville Buncombe Technical Institute Data Processing Program in Dept. of Data Processing	X				X				X			
Campbell College Data Processing Program in Dept. of Business Administration		X				X				X		
Catawba College Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Davidson County Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Duke University Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Durham College Computer Programming Program in Dept. of Business Administration	X				X				X			
East Carolina University Computer Science Program in Dept. of Mathematics						X				X		
Forsythe Technical Institute Data Processing Program in Dept. of Data Processing	X				X				X			

	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Guilford Technical Institute Computer Programming Program in Dept. of Data Processing	X				X				X			
North Carolina State University at Raleigh Computer Science Program in Dept. of Computer Science		X				X	X			X	X	
Richmond Technical Institute Data Processing Program in Dept. of Data Processing	X				X				X			
University of North Carolina at Chapel Hill Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
University of North Carolina at Wilmington Computer Science Program in Dept. of Mathematics		X				X				X		
Wake Technical Institute Data Processing Program in Dept. of Data Processing	X				X				X			
Western Carolina University Information Science Program in Dept. of Information Systems		X				X				X		
NORTH DAKOTA												
North Dakota State School of Science Computer Programming Program in Dept. of Data Processing	X				X				X			
North Dakota State University, Main Campus Computer Science Program in Dept. of Mathematics		X	X			X	X			X	X	
University of North Dakota, Central Office Computer Science Program in Dept. of Computer Science		X				X				X		
OHIO												
Antioch College Computer Science Program in Dept. of Computer Science		X				X				X		
Bowling Green State University, Main Campus Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
Information Systems Program in Several Departments		X	X			X	X			X	X	

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Bowling Green State University, Firelands												
Computer Science Technology Program in Dept. of Other	X				X				X			
Case Western Reserve University												
Computer Engineering Program in Dept. of Computer Science and Engineering		X	X	X		X	X	X		X	X	X
Central State University												
Other Program in Dept. of Mathematics		X				X				X		
Cincinnati Technical College												
Computer Programming Program in Dept. of Business Administration	X				X				X			
Clark Technical College												
Data Processing Program in Dept. of Business	X				X				X			
Cleveland State University												
Computer Science Program in Dept. of Computer and Information Science		X	X			X	X			X	X	
Cayahoga Community College, Western Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			
Denison University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Hocking Technical College												
Computer Science Program in Dept. of Business Administration	X				X				X			
Kent State University, Kent Campus												
Computer Science Program in Dept. of Other		X				X				X		
Kent State University, Trumbull Campus												
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Marion Technical College												
Data Processing Program in Dept. of Business	X				X				X			
Miami University, Main Campus												
Systems Analysis Program in Dept. of Systems Analysis		X				X				X		
Michael J. Owens Technical College												
Computer Programming Program in Dept. of Business	X				X				X			

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
Mount Union College												
Computer Science Program in Dept. of Computer Science		X				X				X		
Muskingam Area Technical College												
Data Processing Program in Dept. of Business	X				X				X			
Muskingham College												
Other Program in Dept. of Computer Science		X				X				X		
Ohio State University, Central Office												
Computer and Information Science Program in Dept. of Computer and Information Science		X	X	X		X	X	X		X	X	X
Ohio University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Systems Engineering Program in Dept. of Industrial Engineering		X	X			X	X			X	X	
Computer Science Program in Dept. of Mathematics							X				X	
Shawnee State General and Technical College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Sinclair Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Stark Technical College												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
Terra Technical College												
Computer Programming Program in Dept. of Business	X				X				X			
University of Akron, Central Office												
Data Processing Program in Dept. of Business	X				X				X			
University of Dayton												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	
University of Toledo												
Information Systems Program in Dept. of Business Administration		X				X				X		
Computer Technology Program in Dept. of Computer Technology	X				X				X			
Wright State University, Central Office												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
OKLAHOMA												
Bethany Nazarene College												
Computer Science Program in Dept. of Business		X				X				X		
Cameron University												
Data Processing Program in Dept. of Other	X				X				X			
Northeastern Oklahoma Agricultural-Mechanical College												
Computer Science Technology Program in Dept. of Computer Science	X				X				X			
Northern Oklahoma College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Oklahoma State University, Main Campus												
Computer Science Program in Dept. of Computer and Information Science			X			X	X			X	X	
Southwestern Oklahoma State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Tulsa												
Computer Science Program in Dept. of Computer Science		X				X				X		
OREGON												
Chemeketa Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Clatsop Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Lane Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Mount Hood Community College												
Computer Science Program in Dept. of Mathematics	X				X				X			
Oregon Institute of Technology												
Computer Science Technology Program in Several Departments	X	X			X	X			X	X		
Southwestern Oregon Community College												
Data Processing Program in Dept. of Business	X				X				X			
University of Oregon, Main Campus												
Computer Science Program in Dept. of Computer Science		X	X			X	X			X	X	

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	76-77				77-78				78-79			
	A	B	M	D	A	B	M	D	A	B	M	D
PENNSYLVANIA												
Beaver Campus, Pennsylvania State University												
Computer Science Program in Dept. of Computer Science	X				X				X			
Beaver College												
Other Program in Dept. of Mathematics		X				X				X		
Beaver County Community College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Bucks County Community College												
Computer Technology Program in Dept. of Computer Science	X				X				X			
Data Processing Program in Dept. of Computer Science	X				X				X			
California State College												
Other Program in Several Departments		X				X				X		
Cheyney State College												
Computer Science Program in Dept. of Computer and Information Science		X				X				X		
Clarion State College, Central Office												
Information Systems Program in Dept. of Business Administration		X				X				X		
Drexel University												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
East Stroudsburg State College												
Computer Science Program in Dept. of Mathematics		X				X				X		
Edinboro State College												
Computer Science Technology Program in Dept. of Mathematics	X				X				X			
Geneva College												
Computer Science Program in Dept. of Computer Science		X				X				X		
Indiana University of Pennsylvania, Main Campus												
Computer Science Program in Dept. of Computer Science		X				X				X		
Juniata College												
Computer Science Program in Dept. of Mathematics		X				X				X		
King's College												
Information Systems Program in Dept. of Information Systems	X	X			X	X			X	X		

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	A	B	M	D	A	B	M	D	A	B	M	D
LaSalle College Computer and Information Science Program in Dept. of Computer and Information Science	X	X			X	X			X	X		
Lehigh County Community College Other Program in Dept. of Data Processing	X				X				X			
Lehigh University Computer Science Program in Dept. of Mathematics			X				X				X	
Lock Haven State College Computer Science Program in Dept. of Computer Science		X				X				X		
Mansfield State College Information Processing Program in Dept. of Computer and Information Science		X				X				X		
Marywood College Information Systems Program in Dept. of Business Administration		X	X			X	X			X	X	
Montgomery County Community College Other Program in Dept. of Other	X				X				X			
New Kensington Campus, Pennsylvania State University Computer Science Program in Dept. of Computer Science	X				X				X			
Northampton County Area Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Pennsylvania State University, University Park Campus Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Philadelphia Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Robert Morris College Information Systems Program in Dept. of Business Administration		X				X				X		
St. Francis College Other Program in Dept. of Mathematics		X				X				X		
Schuylkill Campus, Pennsylvania State University Computer Science Program in Dept. of Computer Science	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
Slippery Rock State College Other Program in Dept. of Computer and Information Science		X				X				X		
Spring Garden College Computer Programming Program in Dept. of Computer Programming	X	X			X	X			X	X		
Temple University Computer and Information Science Program in Dept. of Computer and Information Science		X	X		X	X				X	X	
Thiel College Computer Science Program in Dept. of Mathematics	X				X				X			
University of Pittsburgh Computer Science Program in Dept. of Computer Science		X	X	X		X		X		X	X	X
University of Pittsburgh, Bradford Campus Computer Science and Engineering Program in Dept. of Computer Science and Engineering	X				X				X			
University of Scranton Computer Science Program in Dept. of Computer Science	X	X			X	X			X	X		
Valley Forge Military Junior College Computer Programming Program in Dept. of Mathematics	X				X				X			
Waynesburg College Other Program in Dept. of Mathematical Sciences		X				X				X		
Westminister College Computer Science Program in Dept. of Computer Science		X				X				X		
Wilkes College Computer Science Program in Dept. of Other						X				X		
Williamsport Area Community College Computer Science Program in Several Departments	X				X				X			
Worthington-Scranton Campus, Pennsylvania State University Computer Science Program in Dept. of Computer Science	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
PUERTO RICO												
University of Puerto Rico, Mayaguez												
Computer Science Program in Dept. of Mathematics		X				X				X		
Data Processing Program in Dept. of Other	X				X				X			
World University												
Computer Science Program in Dept. of Computer Science	X	X			X	X	X		X	X	X	
RHODE ISLAND												
Brown University												
Computer Science Program in Dept. of Other		X	X	X		X	X			X	X	X
Rhode Island Junior College												
Computer Science Program In Dept. of Other	X				X				X			
University of Rhode Island												
Computer Science Program in Dept. of System and and Computer Science		X	X			X	X			X	X	
SOUTH CAROLINA												
Florence Darlington Technical College												
Data Processing Program in Dept. of Business Administration	X				X				X			
Furman University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Trident Technical College, North Campus												
Computer Programming Program in Dept. of Computer Programming	X				X				X			
SOUTH DAKOTA												
Black Hills State College												
Computer Engineering in Dept. of Business Administration	X				X				X			
Dakota State College												
Computer Science Program in Dept. of Business Administration	X				X				X			
Northern State College												
Systems Analysis Program in Dept. of Business Administration	X				X				X			
University of South Dakota, Main Campus												
Computer Science Program in Dept. of Computer Science		X				X				X		

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	A	B	M	D	A	B	M	D	A	B	M	D
TENNESSEE												
Austin Peay State University												
Computer Science Program in Dept. of Computer Science		X				X				X		
Cleveland State Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Colombia State Community College												
Other Program in Dept. of Computer Technology	X				X				X			
Freed-Hardeman College												
Computer Science Program in Dept. of Mathematics	X	X			X	X			X	X		
Lambuth College												
Data Processing Program in Dept. of Business Administration		X				X				X		
Memphis State University												
Computer Science Technology in Dept. of Engineering		X				X				X		
Middle Tennessee State University												
Information Systems Program in Dept. of Information Systems		X				X				X		
Motlow State Community College												
Computer Science Technology in Dept. of Computer Science	X				X				X			
State Technical Institute, Memphis												
Data Processing Program in Dept. of Business Administration	X				X				X			
Steed College												
Data Processing Program In Dept. of Computer Science	X	X			X	X			X	X		
Tennessee Technological University												
Computer Science Program In Several Departments		X				X				X		
University of Tennessee at Chattanooga												
Computer Science Program in Dept. of Computer Science	X				X				X	X		
Vanderbilt University												
System and Information Science Program in Dept. of Systems and Information Science		X	X	X		X	X	X		X	X	X
Volunteer State Community College												
Data Processing Program in Dept. of Computer and Information Science										X		

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	A	B	M	D	A	B	M	D	A	B	M	D
TEXAS												
Alvin Community College Computer Science Technology Program in Dept. of Computer Science	X				X				X			
Angelo State University Computer Science Program in Dept. of Computer Science		X				X				X		
Austin College Computer Science Program in Dept. of Computer Science		X				X				X		
Cisco Junior College Data Processing Program in Dept. of Data Processing	X				X				X			
College of the Mainland Computer Science Program in Dept. of Business	X				X				X			
DelMar College Data Processing Program in Dept. of Data Processing	X				X				X			
El Centro College Data Processing Program in Dept. of Business Administration	X				X				X			
Grayson County Junior College Data Processing Program in Dept. of Business Administration	X				X				X			
Houston Clear Lake City Computer Science Program in Several Departments		X	X			X	X			X	X	
Kilgore College Data Processing Program in Dept. of Data Processing	X				X				X			
McLennan Community College Data Processing Program in Dept. of Data Processing	X				X							
Navarro College Data Processing Program in Dept. of Data Processing	X				X				X			
North Texas State University Information Systems Program in Dept. of Information Systems		X				X				X	X	
Odessa College Electronic Data Processing Program in Dept. of Data Processing	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
Paris Junior College Data Processing Program in Dept. of Data Processing	X				X				X			
St. Mary's University Computer Science Program in Dept. of Computer Science		X				X				X		
Sam Houston State University Computer Science Program in Dept. of Computer Science						X				X		
San Antonio College Computer Programming Program in Dept. of Data Processing	X				X				X			
San Jacinto College Computer Science Program in Dept. of Computer Science	X				X				X			
Southwest Texas State University Computer Science Program in Dept. of Computer Science		X				X				X		
Computer Science Program in Dept. of Mathematics		X				X				X		
Stephen F. Austin State University Computer Science Program in Dept. of Computer		X				X				X	X	
Temple Junior College Computer Science Program in Dept. of Computer Science	X				X				X			
Texas A&I University Computer Science Program in Dept. of Computer Science		X				X				X	X	
Texas A&M University Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Texas Christian University Computer Science Program in Dept. of Computer Science		X				X				X		
Texas Southern University Computer Science Dept. in Dept. of Information and Computer Science		X				X				X		
Texas Southmost College Data Processing Program in Dept. of Data Processing	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
Texas State Tech., Rio Grande Computer Programming Program in Dept. of Data Processing	X				X				X			
Trinity University Computer Science Program in Dept. of Computer and Information Science		X	X			X	X			X	X	
University of Texas at Austin Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
University of Texas at Dallas Computer Science Program in Dept. of Mathematical Sciences		X	X	X		X	X	X		X	X	X
University of Texas at Arlington Computer Science and Engineering Program in Dept. of Computer Science and Engineering			X				X				X	
Wharton County Junior College Data Processing Program In Dept. of Data Processing	X				X				X			
UTAH												
Utah State University Computer Programming Program in Dept. of Systems and Computer Science		X				X				X	X	
Weber State College Data Processing Program in Dept. of Computer Science	X	X			X	X			X	X		
Westminister College Computer Science Program in Dept. of Mathematics						X				X		
VIRGINIA												
Central Virginia Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Christopher Newport College Information Science Program in Dept. of Computer Science		X				X				X		
Danville Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Hampden-Sydney College Computer Science Program in Dept. of Mathematics		X				X					X	

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James Madison University Information Systems Program in Dept. of Business		X				X				X		
J. Sargeant Reynolds Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Mary Baldwin College Computer Science Program in Dept. of Mathematics		X				X				X		
National Business College Computer Science Program in Dept. of Computer Science									X			
Northern Virginia Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Old Dominion University Computer Science Program in Dept. of Computer Science		X				X				X		
Radford College Other Program in Several Departments		X				X				X		
Thomas Nelson Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Tidewater Community College Data Processing Program in Dept. of Data Processing	X				X				X			
Virginia Commonwealth University Computer Science Program in Dept. of Mathematical Sciences		X	X			X	X			X	X	
Information Systems Program in Dept. of Information Systems	X	X	X		X	X	X			X	X	
Virginia Polytechnic Institute&State University Computer Science Program In Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Virginia State College Information Systems Program in Dept. of Information Systems		X				X				X		
Virginia Western Community College Data Processing Program in Dept. of Data Processing	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
Washington and Lee University												
Other Program in Dept. of Mathematical Science		X				X				X		
William and Mary, Main Campus												
Computer Science Program In Dept. of Other						X				X		
Computer Science and Engineering Program in Several Depts.			X				X				X	
WASHINGTON												
Big Bend Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Columbia Basin Community College												
Computer Science Program in Dept. of Computer Science	X				X				X			
Gonzaga University												
Other Program in Several Departments						X				X		
North Seattle Community College												
Other Program in Dept. of Data Processing	X				X				X			
Seattle Community College, Central Campus												
Data Processing Program in Dept. of Data Processing	X				X				X			
Seattle Pacific University												
Computer Science Program in Dept. of Computer Science						X				X		
University of Washington												
Computer Science Program in Dept. of Computer Science			X	X		X	X	X		X	X	X
Washington State University												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Western Washington State College												
Computer Science Program in Dept. of Mathematical Sciences		X				X				X		
Yakima Valley College												
Data Processing Program in Dept. of Data Processing					X				X			
WEST VIRGINIA												
Davis and Elkins College												
Computer Science Program in Dept. of Business Administration	X				X				X			

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	A	B	M	D	A	B	M	D	A	B	M	D
Fairmont State College												
Data Processing Program in Dept. of Data Processing	X				X				X			
Glenville State College												
Other Program in Dept. of Computer Science	X				X				X			
Marshall University												
Computer Science Program in Dept. of Computer and Information Science						X				X		
Morris Harvey College												
Computer Science Program in Dept. of Business Administration	X				X				X			
Potomac State College												
Computer Programming Program In Dept. of Computer Science	X				X				X			
Shepherd College												
Data Processing Program in Dept. of Business Administration	X	X			X	X			X	X		
West Liberty State College												
Data Processing Program in Dept. of Business Administration		X				X				X		
West Virginia Institute of Technology												
Computer Science Program in Dept. of Computer Science		X				X				X		
Other Program In Dept. of Business Administration		X				X				X		
West Virginia Northern Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			
West Virginia Wesleyan College												
Computer Science Program in Dept. of Mathematics	X	X			X	X			X	X		
WISCONSIN												
District One Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
Fox Valley Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
Madison Area Technical College												
Data Processing Program in Dept. of Data Processing	X				X				X			

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Milwaukee Area Technical College												
Data Processing Program In Dept. of Business Administration	X				X				X			
Computer Science Technology Program in Dept. of Electral Engineering Technology	X				X				X			
North Central Technical Institute												
Data Processing Program in Dept. of Computer Programming	X				X				X			
Northeast Wisconsin Technical Institute												
Computer Programming Program in Dept. of Data Processing	X				X				X			
University of Wisconsin, Eau Claire												
Computer Science Program In Dept. of Computer Science	X				X				X	X		
Information Systems Program in Dept. of Other		X				X				X		
University of Wisconsin, La Crosse												
Computer Science Program in Dept. of Computer Science		X				X				X		
University of Wisconsin, Madison												
Computer Science Program in Dept. of Computer Science		X	X	X		X	X	X		X	X	X
Information Systems Program in Dept. of Business Administration		X	X	X		X	X	X		X	X	X
Other Program in Dept. of Other		X	X	X		X	X	X		X	X	X
University of Wisconsin Superior												
Computer Science Program In Dept. of Mathematics		X				X				X		
Data Processing Program in Dept. of Business Administration		X				X				X		
Western Wisconsin Technical Institute												
Data Processing Program in Dept. of Data Processing	X				X				X			
WYOMING												
Northwest Community College												
Computer Science Program In Dept. of Computer Science	X				X				X			
University of Wyoming												
Computer Science Program in Dept. of Computer Science		X				X	X			X	X	

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Western Wyoming Community College												
Data Processing Program in Dept. of Data Processing	X				X				X			